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FINAL PROJECT REPORT

DAYLIGHT METRICS

PIER Daylighting Plus Research Program

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PREFACE

The California Energy Commission Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

Daylight Metrics is the final report for the Daylight Metrics project, contract number 500-06-039, conducted by Heschong Mahone Group. The information from this project contributes to PIER's Buildings End-Use Energy Efficiency Program.

When the source of a table, figure or photo is not otherwise credited, it is the work of the author of the report.

For more information about the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

ABSTRACT

This report presents the results of the activities and results of developing an annual performance metric for daylighting (natural light). The report builds upon existing knowledge about the use of daylight and buildings and provides the background needed for establishing a new metric. A detailed discussion of data collection and analysis is provided to support the findings. The report describes a range of potential metrics that were explored and tested against the collected data, before deciding on "Spatial Daylight Autonomy" as the best descriptor for daylight performance in a space. Spatial Daylight Autonomy describes the proportion of a building space that is fully illuminated by daylight for a certain portion of the year. Defining a daylight performance metric offers the potential of a uniform reference for simulating daylighting performance in a space and for developmenting daylight performance standards in building and energy codes that would increase ratepayer satisfication with daylighting technologies enabling more widespread adoption. Buildings that incoprate more daylighting can reduce electric lighting which can lead to significant energy savings.

Keywords: California Energy Commission, daylighting, lighting, codes and standards, building simulation, daylight metric, spatial daylight autonomy.

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EXECUTIVE SUMMARY

Introduction

This report presents the field study results of a project to develop a set of daylight metrics that describe a "well-daylit space." The metrics focused on human visual comfort, not on energy performance, since it is necessary to establish comfort performance goals before energy use can be optimized. This is necessary so that manufacturers can develop technologies and building designers can optimize systems that not only save energy but are preferred by consumers, leading to full market adoption.

Purpose

The overall goal of this project is to increase the use of daylighting in buildings that will save energy, reduce peak electricity demands, and improve occupant comfort and satisfaction in those buildings.

Objectives

The main objective of this project is to develop a set of daylight performance metrics and criteria, in cooperation with national and international leaders in the field, which can be used in building specifications, efficiency programs, codes and standards to promote more successfully daylit buildings, and thus result in greater energy savings and demand reduction.

Other objectives of the project are that, after development of the performance metrics and criteria:

- At least one California Investor Owned Utility (IOU) program will adopt the daylighting criteria to describe minimum performance for its new construction or retrofit program,
- Voluntary standards, such as the Collaborative for High Performance Schools (CHPS) and Leadership in Energy and Environmental Design (LEED), will reference these criteria, and
- Proposals will be made to reference the criteria by California's Title 24

Approach

1. Develop a research plan, including the formation of an Advisory Committee, to comment on need and utility of findings.
2. Conduct qualitative evaluations of a range of daylit spaces by occupants and a select group of lighting experts.

3. Develop annual hourly daylight simulation models for each studied space to predict the daylight distribution patterns over time, accounting for climate and building operation. .

4. Compare the qualitative evaluations to the quantitative output of the simulation models to test the predictive power of alternative metrics.

5. Recommend a suite of metrics can most usefully describe expected occupant comfort in daylit spaces.

6. Coordinate the methodologies, findings and recommendation of this project with the work of key user groups, such as the Daylight Metrics Committee of the Illuminating Engineering Society of North America (IES) and building simulation software developers.

7. Make the project's knowledge gained, experimental results and lessons learned available to key decision-makers and the public.

Research Accomplishments

The study focused on three space types, defined by shared visual tasks, that were judged most in need of daylighting performance metrics, and feasible to study within the project limitations:

- **Classroom space type**, including conference rooms, with group discussions in addition to paper and computer based tasks at the desk or on wall surfaces.
- **Open office space type**, with stationary workers performing paper and computer based tasks at the desk, along with associated phone calls, filing and small face-to-face meetings.
- **Library/lobby space type**, with occasional visitors moving about the space performing a wide range of tasks, with many choices for task location.

The study spaces were located in three states (representing the three original funding sources) and six urban areas:

- California—San Francisco/Oakland, Sacramento, and Truckee
- Washington State—Seattle/Tacoma
- New York State—Albany, and New York City

The climates and locations represented varied from coastal to inland, urban to rural, from moderate to temperate, from very sunny to very overcast, and with and without snowy winters.

A range of daylit spaces were identified for study, with the goal of including as wide a range of daylighting strategies and performance levels as possible within the three space types. The final study sample included both side and top lit spaces, with both single and multiple orientations. A variety of daylighting strategies were represented, including light shelves, skylights, clerestories (upper part of a wall containing windows for daylighting a space), translucent glazing, and advanced blinds, along with simple view windows with a variety of tints and shading conditions.

A rotating group of 18 experts visited 77 candidate spaces over the course of a few weeks in the summer of 2007. Sixty one of these spaces were selected for further study. Qualitative assessment surveys were collected for each space, averaging 9.5 occupants and 5.2 experts per space. Two groups of survey questions were used to assess 'daylight sufficiency' and 'glare'. Statistical analysis was used to compare experts' and occupants' responses to various candidate metrics of daylight performance generated from the annual simulation output described below.

Physical conditions were documented at the selected study spaces sufficiently to develop highly detailed three dimensional computer models, using *Ecotect*, for importation into *Radiance*. The computer models included detailed geometry of the spaces, surface reflectance, interior furniture layout, exterior obstructions including vegetation and buildings, and type of blinds or shades for each window group.

Operation of window blinds or shades became a major challenge of the simulation process. Most of the study spaces (57%) had more than one orientation of fenestration, and operable blinds or shades were found in 84% of all the spaces. Most of the spaces without blinds had no view windows, i.e. only skylights or translucent glazing. Modeling blinds operation, hourly by orientation, was a necessary capability of the simulation tool for generating annual daylight conditions in the study spaces.

The rigorous blinds operation protocols necessitated the development of a new software tool to implement this methodology. In collaboration with LBNL, the project team helped develop and beta test a new annual lighting simulation capability for *Radiance*. The annual simulations used the weather data known as Typical Meteorlogical Year 2 or TMY-2. This weather data was used to generate hourly illuminance (light levels on a given surface) data for one-foot sensor grids in each study space. Sensors were placed at task level, eye level and ceiling level (looking down) and reported hourly illuminance for two conditions: 'Blinds Open' and 'Blinds Closed'. This data was then combined into a 'Blinds Operated' case, according to an hourly sun exposure schedule also generated for each space.

A large number of candidate daylight performance metrics were generated from the simulation output. They focused on four main concepts: daylight sufficiency, sun penetration, uniformity, and other glare proxies. Using multivariate statistical analysis, the candidate metrics were tested against the independent variables defined from the expert and occupant surveys. Metrics that best predicted occupant and expert assessments, and were stable across all three space types, were considered further.

The results of the analysis were presented to the IES Daylight Metrics Committee for discussion and feedback. Discussion included how the metrics could be applied in practice and translated into performance criteria for codes and design specifications.

Conclusions

Overall, a 300 lux illuminance threshold was found to be the best predictor of expert and occupant assessments of daylight sufficiency for all three space types combined. The Committee agreed, however, that other illuminance thresholds might be useful for other space types. A metric named zonal Daylight Autonomy, or zDA, was initially described for reporting the percentage of combined sensor-hours in a given space that exceeded 300 lux throughout the year's analysis period, from 8 AM to 6 PM local time.

No level of annual daylight illuminance was found to be 'too high', i.e. to predict occupant discomfort. Indeed, low levels of daylight illuminance were found to most strongly predict occupant discomfort relative to contrast, reflections or glare. Given these findings, the committee elected not to recommend an upper limit to daylight illuminance.

Other proxies for glare or visual discomfort were explored, without general success. The size of view of the sky did not predict responses to the visual comfort survey questions, nor did the number of window orientations. Many metric options to predict uniformity were tested but all were judged inadequate.

The metric most successful at predicting visual discomfort was the maximum number of hours per year that sunlight could potentially enter the space, assuming the blinds were always left open, and accounting for local weather. Less than 350 hours of sunlight at any one point in the space per year predicted a clearly positive evaluation, while a neutral or slightly positive response was observed for less than 600 hours per year.

The Committee voted on various components of and formats for a 'daylight sufficiency' metric. It was named 'spatial Daylight Autonomy', or $sDA_{300/50}$, and reports the percent of area in a space or building that meets or exceeds 300 lux of daylight illumination for 50% of the year, i.e. 1825 hours. A space that met or exceeded $sDA_{300/50}$ in over 75% of a given space resulted in a clearly positive assessment and was thus considered 'preferred.' A space that met or exceeded $sDA_{300/50}$ in over 55% of a given space resulted in a neutral or slightly positive assessment, and was thus considered "nominally acceptable."

Two limitations to these recommendations should be considered:

- There is a great deal of variation in preferred comfort conditions within the population and therefore one should not expect such a metric to precisely predict individual occupant response; and

- Additional descriptors of daylight quality will be necessary in order to increase the precision in describing a "well-daylit" space.

A second metric was under development by the Committee at the time of writing, tentatively named Annual Sun Exposure (aSE), to describe the maximum exposure risk to sunlight that should be acceptable in a daylit space. The goal is to create a sun exposure metric that will work in harmony with sDA, and be equally useful to designers and specifiers.

Going forward, the Committee intends to write an IES Lighting Measurement document, detailing the methodology for generating these two new metrics (sDA and aSE), and eventually a Design Guide for designers and code developers about how to apply and select performance criteria appropriate to their application.

Recommendations

To be truly successful, the simulation capabilities pioneered in this project, and used to develop the recommended metrics, need to be made easily available to manufacturers and architects, via professional-grade simulation tools. Furthermore, better performance data on advanced daylighting products to feed into those simulation tools is also needed to realize the full potential of daylighting in the market.

The findings on the three space types should be validated by others, and the research methods extended to other space types and climate locations. Current understanding of visual comfort under daylight conditions is very limited and needs more comprehensive study, both in controlled laboratory settings and also in field settings, where occupant behavior, especially blinds operation and glare avoidance, under real conditions can be observed, and hopefully eventually predicted.

Benefits to California

The ultimate goal is a suite of daylight performance metrics that, taken together, can better predict occupant comfort in daylit spaces, and thus be used to set minimum standards for daylighting in buildings. Minimum standards for daylighting in buildings will benefit California ratepayers by influencing a greater amount of daylighting in buildings which will result in a need for less electric lighting thus saving ratepayers on electricity costs.

Daylighting has the potential to reduce peak lighting loads by 25-50% in most commercial building types, including both new construction and existing buildings. Up to 80% reductions in lighting energy use have been observed in some buildings designed to optimize daylighting use. Looking strictly at existing office buildings in California, there is a technical potential to save over 400 Gigawatt hours annually and reduce peak demand by over 180 Megawatts. Considering all commercial buildings statewide could increase these savings by 5 or 6 times.

CHAPTER 1: Introduction

1.1 Background on the Daylighting Plus Program

The goal of the Daylighting Plus PIER research program is to promote a better understanding of daylighting potential, strategies and metrics to increase energy savings from daylighting and associated electric lighting in commercial buildings in California. This is to be achieved through a coordinated suite of research projects and related market connections activities.

Led by the Heschong Mahone Group, Inc., the Daylighting Plus program consists for four program elements addressing the appropriate use of daylight:

- The Daylighting Metrics Project, addressed by this report, worked with the IESNA and an international team to develop and test new daylight performance metrics and criteria, based on annual simulations. The goal is for these metrics to provide better criteria for appropriate daylighting design, tailored to climate, building operating characteristics, and advanced design options, which can then be adopted into codes and voluntary standards.
- The Retail Revisioning Project worked with Federated Department Stores and other retail designers and owners, to develop and demonstrate daylighting design approaches for "fancy box" retail stores that can both enhance visual marketing and provide significant energy savings.
- The Office Daylighting Potential Project set out to quantify the market potential for retrofitting existing office space in California to maximize daylighting energy saving potential, and develop assessment tools for new daylighting retrofit programs.
- In addition, a program-wide market connections effort assisted the project-level objectives by hosting outreach events and forums for discussion of the range of issues addressed by this program, and of concern to the PIER Program. These activities facilitated the exchange of knowledge generated by this program with the appropriate audiences, and generated further discussions and market connections among the participants.

Reports for the other three Daylighting Plus PIER elements are available separately from the California Energy Commission at http://www.energy.ca.gov/research/ [Hescong 2011b, Pande 2011, Saxena 2011].

1.2 Introduction to the Daylight Metrics Project

Daylighting is often touted as one of the best win-win strategies for "high performance" or "sustainable" buildings. It provides the highly visible benefits of an architecturally beautiful and memorably lit space, and one that is potentially low maintenance and low energy while also enhancing the comfort and well-being of the occupants. However, there is also often a presumption that because daylighting is "natural" it should also be very simple. We are all familiar with older buildings that provide beautifully daylit spaces, suggesting that good daylighting design can be very low-tech, even intuitive. However, such an assumption belies the centuries of building experience that went into developing those traditional buildings. Now, with many new sophisticated fenestration technologies available, and vastly more demands on the performance of buildings, especially for dramatically reducing energy performance while maintaining human health and comfort, there is a need for advanced metrics and analysis methods to help optimize daylighting design under these new conditions.

1.2.1 Daylighting Involves a Lot of Moving Parts

Everyone understands intuitively that daylighting illumination will vary throughout the day. Between dawn and dusk the sun changes position and intensity as it moves across the sky, shining through various atmospheric conditions and reflecting off surfaces. The very same window will produce completely different illuminance patterns inside when there is fresh snow on barren trees in spring and tall grass and leafy trees outside in fall, even the exactly the same sun position and sky conditions.

Seasons and weather are just the beginning of the moving parts, or dynamic variables, that influence daylight availability and efficiency. The glazing required for daylighting also has an impact on cooling and heating loads of buildings as a result of radiant and conductive heat transfer. Intuitively, smaller and darker windows should reduce cooling and heating as the thermal conductivity of windows are higher than walls and darker glass allows less radiant heat gain. However, because daylight can transmit less heat into a building space for given amount of illumination as compared to electric lights, there is not only the savings of lighting energy when lights are turned off or dimmed, but also potential for reduced internal gains which can impact either cooling energy savings or increased heat loads. The balance point between such losses and gains is a complex equation, which can not only vary seasonally, but even hourly, depending on the climate conditions, building operation and equipment efficiency. For large, commercial buildings which are internal load dominated, cooling savings often predominate.

A case could be made that daylighting is one of the most interdependent functions in a building, requiring careful integration with all building systems. It is deceptively simple—since we experience daylight directly every day—but devilishly difficult to predict with precision. Over the years designers have developed simplified approaches that help estimate how much daylight to expect within a given space. The accuracy of those predictions has evolved over time, along with the available tools.

1.2.2 A Brief History of Daylighting Performance Metrics

The science of determining adequate levels of daylighting for buildings began to develop in the early decades of the twentieth century. Urban density was increasing, along with industrial smogs, reducing daylight access to workplaces and schools, and electric lighting industry began to take over the role of providing illumination during the daytime. It is not coincidental that Britain also experienced a rash of childhood rickets at this time, making prediction of adequate daylight a growing health concern. [Loveland 2006]

In the 1940s and 1950s, the British Building Research Establishment (BRE) began to develop manual calculation tools, such as nomographs and "pepper pot" diagrams that supported more precise estimation of a "daylight factor" or the ratio of daylight illumination available outside to that resulting inside of a space. The method greatly simplified the problem by ignoring the contribution of direct sunlight, calculating only the contribution from a standardized overcast sky—a simplification that was deemed sufficient given the often cloudy British climate.

In the 1950s and 1960s, these BRE methods were widely adopted; for example, in California, the State Architect required such hand-calculations to show that all school classroom designs would achieve minimum levels of daylight illumination, while preventing sun penetration during normal classroom hours. The concern at the time was with lighting quality. Today these classrooms still provide admirable daylighting illumination [See SMF03sp1 and SMF03sp2 in Appendix D.2], but their energy performance can be worrisome, due to single pane windows and the subsequent addition of air conditioning.

In the 1970s and 1980s, rapidly rising oil prices sparked interest in building energy efficiency and the efficiency potential of daylighting. A surge in national research funding helped to develop such advancements as low-e windows, insulated window frames, and photosensors which could control newly invented dimming ballasts. The first energy simulation programs such as Blast and DOE2 were developed to support whole building energy optimization, along with ray-tracing programs such as Radiance to produce accurate renderings of illuminance patterns.

1.2.3 The Current Situation

Fast forward 30 to 40 years and, after decades of relative neglect, practitioners find themselves still citing the daylighting performance research work done in that period. In spite of vast advancements in computational capability, and interface expectations based on iPhones and 3D animation, the basic computer analysis tools for daylighting are those developed in the 1980s.

Many codes and standards currently rely on very simple prescriptive criteria, such as window head heights, or the daylight factor inherited from the BRE, to specify daylight performance. Although these simple prescriptive requirements might encourage greater use of daylighting, they cannot distinguish between better or worse approaches. For example, using the geometric prescriptive measure of head height, all spaces with windows at a 8′ head height appear to have equally good daylighting, regardless of orientation, climate location, glass type, exterior obstructions, shading devices, or the use of the space. And without greater ability to predict daylighting performance, advancements in daylighting technology and design optimization have been inhibited—if better and worse performance between products or strategies cannot be differentiated, there is no added value to sell, and there is no basis for optimizing and improving performance.

Furthermore, poor daylighting specification can lead to worse energy performance. A daylight factor analysis was performed for six monitored building spaces in California that were reasonably well daylit and saving substantial energy via daylighting controls [Heschong 2006]. However, none of these spaces came close to achieving the then current LEED criteria of an average of 2 percent Daylight Factor" throughout the space [USGBC 2005]. Had they been designed to meet those criteria, substantially larger glazing area would have been required and the whole building net energy impacts would likely have been negative.

In an effort to improve on such limited prescriptive measures, some groups setting standards for high performance buildings, such as USGBC, are scrambling to adopt new metrics of annual daylighting performance. However, they have had little guidance on what the numbers mean or defining methodologies to achieve them. The Collaborative for High Performance Schools (CHPS) was one of the first of these groups to adopt a suite of daylighting performance alternative paths in 2004 [CHPS 2006], but did so with little basis for choosing any of the published values[1].

Motivated by these needs, there has been substantial progress in the conceptual evolution of more sophisticated daylighting metrics during the last decade. A suite of alternative annual simulation-based daylight metrics, often described as dynamic or climate-based metrics, have been proposed [Mardaljevic 2000a and b; Reinhart 2001; Reinhart 2006a]. However, there was very little data provided help interpret any of these proposed metrics, such as appropriate thresholds and criteria for a given space type or how to predict occupant satisfaction with the resulting visual quality. Furthermore, methodologies to generate the metrics were inconsistent at best, or poorly documented, making comparisons and further research difficult.

1.2.4 IES DMC and Related Efforts

In 2006[2], a subcommittee of the IES was convened to help guide research and development of a set of new annual simulation-based performance metrics that could be used to specify the need for daylighting performance in buildings (hereafter referred to as “IES DMC” or “the committee”). It was the outgrowth of an earlier “informal

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[1] One of the authors of this paper served on the technical committee developing the daylighting performance criteria for CHPS, and so has first-hand knowledge of the lack of information available at that time.

[2] The subcommittee was promoted to a full committee by the IES board as of February 2011, and so is hereafter referred to as ‘the Daylight Metrics Committee” or IES DMC.

working group" and an even earlier "Daylighting Council" meetings held privately and at various association meetings. Given that the IES is a standard setting organization focused on lighting quality, the IES DMC members agreed that the IES would be the best host for these activities and repository for their recommendations.

Shortly after the DMC was formed, this PIER project was initiated. The DMC has provided ongoing peer review and research advisory support to the PIER project team since the project's inception. In turn, the project team has provided data to the DMC for its use in formalizing metrics, processes and eventually daylighting criteria. The PIER project Principal Investigator has served as the Chair of the DMC, and several of the committee members also served as subcontractors on the project team to complete specific tasks. A number of other DMC members also volunteered to serve as "experts" for the PIER field study. A list of current DMC members is included in Appendix B.1. The DMC work will continue beyond the conclusion of this PIER project, to document and deploy the selected metrics, and continue to refine IES recommendations on the topic.

In addition to the IES DMC, a number of other organizations have become increasingly active in efforts to establish daylight performance metrics during the same time period as this work. Given the level of activity, a number of efforts were made to coordinate across the groups and inform the discussions.

- Adhoc Daylighting Code Coordinating Committee

  In early 2010, many organizations were simultaneously considering changing the daylighting provisions in their code language. to facilitate coordination, the chair or a key member from each group was invited to participate in a series of conference calls to share approaches and concerns. The participants in these calls are also listed in AppendixB.1.

- Daylighting Forum

  As part of the market connections task for this PIER program, and with additional funds from other sources, an invitation-only Daylighting Forum was held immediately after LightFair 2010 in Las Vegas, NV. About 100 attendees discussed the needs for daylight metrics, currently available tools, and necessary next steps for deployment. A report on that forum is available in the associated report [Heschong 2010b]

The related daylighting efforts are listed briefly below to help set the context for this work. The implications for each are discussed further at the end of the report under Section 5, Next Steps.

- California Energy Efficiency Standards 2013, Title 24 and CalGreen

  The California Investor Owned Utilities (IOUs) are funding code change proposals for the next version of the California Energy Efficiency Standards 2013 and the associated 'green reach", known as CalGreen. HMG is one of the prime contractors on this effort, and has been utilizing the methodology developed for this PIER project to develop the justification for more stringent daylighting and photocontrol requirements in these two codes. Those code proposals area available for review [CASE 2011]. A series of stakeholder meetings were held in 2010 and 2011 by the IOUs to solicit input, and additional public workshops will be help by the CEC in 2011for further input. http://www.energy.ca.gov/title24/

- USGBC and LEED

  The United States Green Building Council is in the process of updating the daylighting and view credits in its Leadership in Energy and Environmental Design for the 2012 edition (LEED v.4). A subcommittee of the Environmental Quality Technical Committee is reviewing proposals to change these credits as this report is being written. www.usgbc.org.

- IgCC and ASHRAE 189

  The International Green Construction Code (IgCC) has effectively merged with ASHRAE's 'green reach code', Standard 189, in that they will be published together and local jurisdictions will have choice of which to adopt. The development committees worked separately, 189 ahead of IgCC, so the daylighting language of the two codes is not (yet) comparable. The IgCC is a project of the International Code Council, www.iccsafe.org.

- CHPS

  The Coalition for High Performance Schools, started in California, is now a national non-profit organization, with slight variations in its daylighting provisions according to adopting state. The California technical advisory group has been waiting for the completion of the DMC recommendations before considering new changes to the daylighting requirements. www.chps.net

- ASHRAE 90.1, envelope and lighting committee

  As the ASHRAE envelope and lighting committees considered new changes for adoption in 2011, conflicts between daylighting goals and thermal energy impacts became evident. Addendum bb, which specified new, substantially lower, SHGC and window-to-wall ratio (WWR) requirements, was proposed to be modified with Addendum cx, which allowed a path for higher values accompanied by mandatory dimming photocontrols. Ultimately, Addendum bb was challenged and disallowed. Analysis from this project helped to support the need for a minimum VLT, or greater effective aperture (WWR*VLT). http://www.ashrae.org/

- IeCC

  Changes to the International Energy Construction Code were largely completed ahead of the ASHRAE proposals. IeCC did not adopt the lower 30 percent WWR originally proposed in ASHRAE Addendum bb. Some committee members have expressed an interest in finding other language to enable greater usage of daylighting in future editions. www.iccsafe.org

- NFRC

  The National Fenestration Rating Council (NFRC) has formed a daylighting rating task group to consider the needs and format for a potential daylighting rating system for fenestration, tubular daylighting devices, and "attachments", such as blinds, shades and awnings. To date, the NFRC has used Visible Light Transmission (VLT) and Solar Heat Gain Coefficient (SHGC) values determined 'normal' to the product, such as at a 90 degree angle, regardless of solar position. A more nuanced rating system will need to account for variable angle of incidence and transmission. www.nfrc.org

- Velux Daylight Symposium

  Held every other year since 2005, the Velux company has sponsored an international symposium on daylighting research and application. Held in various cities in Europe, the Symposium has enabled the international daylighting community to gather and discuss progress and needs in the field. http://www.thedaylightsite.com/

- CIE TC 3-47 Committee, Climate Based Daylight Modeling

  In 2008 a Technical Committee for the International Commission on Illumination (CIE) was formed to coordinate the development of daylighting performance metrics among its members. A list of current TC members is included in Appendix B.1 http://www.cie.co.at/div3/docs/mardaljevic-cie-rs.pdf

1.2.5 User Types and Needs

Any set of metrics should meet the needs of all the people who will likely use it. In the case of daylighting this includes a wide range of "stakeholders" from researchers and academics who want precision and flexibility, to building occupants and practitioners who want simple, but correct, answers. Below is a list of a range of different needs, and a sampling of the types of users who have some interest in daylight performance metrics: In one way or another, all of these people want an answer to some form of the basic questions: "how much of this space is daylit?" and/or "how well is this space daylit?"

- Performance goals
  - Design Guidelines (IES, ASHRAE)
  - Utility program participation requirements
  - Voluntary standards (LEED, CHPS)
  - Performance path for code requirements
- Design prediction and optimization

- Simulation tools used by architects, lighting designers
- Utility efficiency programs
- Product manufacturers, proof of value of products
- Researchers and educators, to evaluate designs

- Building specifications
  - Owners, to set design performance goals
  - Real estate procurement
  - Prescriptive code requirements
- Code compliance
  - Language for requirements
  - Plan check
- Field verification
  - Occupants and owners, to verify quality of their spaces
  - On-site verification by code officials
  - Utility program evaluation, to verify compliance with program requirements
  - Appraisers, to describe the performance of building
  - Researchers, for post-occupancy evaluation
- Building stock descriptions
  - US Census, CBECs, EIA, CUES
  - Appraiser comparisons
  - Benchmarking comparisons

Ideally, the same metrics could be used for all these purposes, but with varying degrees of accuracy and perhaps with modest modifications to the methodology used to generate them. Also, ideally, the same metrics could be predicted via simulation and verified via field measurements.

1.2.6 Metrics versus Criteria

A metric is a useful mathematical combination of measurements and characteristics that is then set onto a continuous scale. Common examples include body mass index or miles per gallon, which combine a number of dimensions into a single value. The term "metric" implies a more complex assembly of information that a simple direct measurement, and as such, it may not be directly measurable in the field. The difference between a metric and a criterion was usefully discussed in on overview of daylight metrics published in LR&T in 2009:

"*A criteria is a demarcation on that metric scale that determines if something passes or qualifies, for example three-quarters of the workspace area achieves a 2 percent daylight factor. The purpose of a metric is to combine various factors that will successfully predict better or worse performance outcomes, and so inform decision making.*

Performance may be described by more than one metric, for example it is not necessary to combine all significant factors into one metric. The most useful metrics have an intuitive meaning for their users and can also be directly measured for validation. This implies a preference for simplicity so they can be intuitively understood, and a direct tie to measurable outcomes. When metrics are succinctly refined and understood and their predictive capabilities validated, then performance criteria can be set for various guidelines and recommendations." [Mardaljevic 2009]

1.3 Goals for Annual Performance Metrics

The committee made a number of key decisions about the needs for and likely uses of the metrics, which logically led to determining the project research plan, and the outcome of the metrics format and methodologies. Some of these key decisions are described below:

1.3.1 Metric Objectives

Analysis by space, not by building. The unit of analysis chosen was a space, not a building, much as it is for electric lighting. Much as an HVAC zone is a semi-autonomous area served by one HVAC control system, a "space" for the sake of this analysis has a coherent daylighting illumination pattern created by one or multiple apertures that all contribute daylighting into an overlapping area. A daylit space could be subdivided by translucent partitions if they allow the daylight to mostly pass through or around them.

Comparison of alternative strategies and populations of spaces. This mandated that the methodology to generate the metrics could support any spatial geometry or daylighting strategy, and be equally fair to all strategies and spatial configurations. For example, illumination gradients are difficult to describe without a clear starting point, and many daylit spaces don't have an obvious front or a back, or even orthogonal relationships. Likewise, glare criteria that require a fixed point of view would not be useful if the point of view chosen was not comparable across all spaces.

Focus on visual comfort. The subcommittee agreed that daylighting illumination performance was poorly defined and not well served by metrics developed for electric lighting. For example, task and ambient illuminance will inevitably fluctuate in a daylit space. How wide a range of illuminance over time or across a space is acceptable? Likewise, contrast ratios that might be considered glaring in an electrically lit space might be welcomed in a daylit space, especially when looking out a window. None of the existing electric lighting metrics are capable of addressing the dynamic nature of daylighting, nor are they likely to match occupants' expectations of how lighting in a daylit space might differ from that in a wholly electrically lit space. Thus, the committee set as a goal achieving a suite of metrics that would include daylight sufficiency (task illuminance) over space and time, but also metrics that could help qualify the occupants' experience of visual comfort achieved within the space.

Focus on daylight illumination quality, not energy performance. The quantity and quality of daylighting in a space should be important determinants of electric lighting use in the space, but there are far too many additional variables to predict electric lighting energy use or whole building energy impacts directly from daylight availability. Once preferred daylight patterns are obtained, an appropriate electric lighting design strategy and control logic can be crafted. Thus, the committee agreed that daylighting performance should first be a basic human comfort issue, similar to adequate electric lighting or adequate ventilation.

For example, in the HVAC world, it is well understood that humans have needs for minimum ventilation and air quality that must be met by an HVAC system, even though additional ventilation may add to the energy needs of a building to maintain thermal comfort. Thus, standards for ventilation are based on human well-being criteria, not energy performance. The energy performance is the efficiency of the system that meets those needs.

Just as electric lighting use is only loosely related to daylighting patterns, so to HVAC energy use cannot be predicted directly from the daylight illumination patterns of the space. Consider that the daylight illumination quality in two geometrically identical spaces could be identical while the HVAC requirements for the spaces could be very different. As a thought exercise, imagine a set of sister classrooms with a large south facing windows. The fenestration in one classroom might be a tinted single-glazed window with very poor U-value and SHGC while next door an identical classroom had been retrofitted with a triple glazed assembly with exemplary thermal performance. However, both windows could have the same visible light transmittance at 50 percent VLT, resulting in identical daylight illumination conditions. Furthermore, a pair of these classrooms set in San Francisco and Saint Louis, two cities with nearly identical sun paths but very different seasonal climates, will get radically different thermal comfort needs and resulting energy impacts of the daylighting design. Thus, daylight illumination performance should not be taken as a proxy for electric lighting use or whole building energy impacts.

Useful in codes, standards and specifications. While there were numerous methodologies available to study and guide the design of daylight spaces, such as physical models and 3D renderings, there was little agreement on how to compare performance across spaces or how to specify that a space would achieve acceptable daylighting performance. A wide variety of users, owners and regulators need a way to request that daylighting be provided in their buildings and to verify that their request had been met. By implication, these users need a set of metrics that can be useful for comparison throughout the full sequence of a building's life, from conceptual design through construction and operational phases. The ability to compare relative performance <u>across</u> spaces and design strategies with a consistent methodology thus becomes more important than single-point-in-time accuracy for optimizing a single design. This requirement led to a committee recommendation for a hierarchy of "levels of analysis" (discussed further in Section 1.3.2) and rule sets that would create a 'level playing field' for comparing results across designs, with standard default assumptions and methodologies.

Capable of optimizing annual performance. While some single-point-in-time metrics, such as Daylight Factor or "achieving 25 foot-candles at noon on equinox", do provide a performance criteria, they do not provide enough information to evaluate whether a given design strategy will perform better or worse over the course of a normal year's weather conditions or in different locations. Without the ability to optimize over a year's weather, it is not possible to differentiate between many advanced technologies, or gauge their impact on a building's other dynamic energy systems. Simulation programs which are used to derive the annual performance metrics must therefore accurately model daylighting systems that have a variable performance over the course of a year, such as highly variable light transmission as a function of solar angle (as do light shelves and shaped skylights) or dynamic response, from simple operable window blinds or highly automated tracking skylights.

Standardize metrics methodology, not criteria. Eventually, once the format of metrics and the methodology for generating them are agreed upon, the committee will be able turn its attention to discussing performance criteria, which can vary by application. Following the example of mileage ratings for vehicles, strict EPA protocols must be followed in testing a vehicle's miles per gallon rating so that comparisons between product lines is valid, but the acceptance criteria can vary depending on the vehicle type or driver's needs. Similarly, a standardized daylighting performance metric should have a well understood format and methodology that can be universally compared across spaces, but the application criteria could vary by space type, climate location, or stringency needs.

Set a path for the future. It is important to have a path that can guide not only the development of immediately feasible metrics, given the limitations of current simulation tools, but also gives a logical progression for refinement as tools became more capable, and for inclusion of additional performance metrics as further research becomes available. Simplistic metrics that might quickly become technically obsolete need to be avoided as they have a tendency to persist through cultural inertia. The subcommittee hoped to create a public forum where research needs could be prioritized in support of the development of better daylight performance metrics and understanding of visual comfort and human physiological needs under daylit conditions. As such, the project needed to push the limits of what was feasible with current methods, and anticipate future needs and capabilities.

For example, the committee determined that while analysis by hourly illuminance was currently within reach, given available simulation tools, that corresponding analysis by luminance is very important but should wait for the future (See discussions on glare analysis in Sections 4 and 5). Similarly, given the complexity of human motivations for having interior spaces with windows and daylight, future daylight metrics might additionally address the quality of views or circadian stimulus provided in those spaces. A few researchers [Reinhart 2006a, Howlett 2007, Peachacek 2008, Kliendienst 2008] have started to tackle these issues, but with the very limited funding currently available for research in these areas it is unlikely that progress will be made quickly.

1.3.2 Three Levels of Analysis

At the outset of the project the IES DMC discussed the range of uses for the proposed metric and proposed the concept that there could at least three levels of analysis to satisfy the variety of user needs [Heschong 2010]. These three levels are described below.

It was the original intent of the project to study spaces at the most detailed (post-occupancy) Level Three, and then to eventually calibrate those results back down to the simplest (schematic) Level One analysis. However, that final step was not achieved in this effort. It has been pursued more rigorously in the companion study Office Daylight Project: Final Report [Saxena 2011], part of the larger Daylighting Plus PIER Program, and the Daylighting CASE report for Title 24 [CASE 2011]. Thus, the remainder of this report will discuss only the modified version of Level Three analysis used in this field study, and described in detail in Section 3 and Appendix C.

Level One is the simplest level of detail, appropriate to test the performance of alternative design strategies. This level of analysis would be appropriate to guide early schematic design, allowing quick iterative runs, or to show compliance with daylight performance standards, such as LEED or CHPS or the International Green Construction Code (IgCC), for simple buildings. A requirement for quick and easy modeling suggests reduced granularity of geometric detail and analysis grids, and also implies that a variety of professional-grade tools would be available to generate the required metrics. This level would use default assumptions for most conditions that are not knowable during early design, and optimistic assumptions about user operation and reflectances, to define the upper limit of the "daylight potential" for the space. Window conditions would be defined with simplified two-dimensional openings, surface reflectance as standard defaults, furniture ignored or defaulted to simple assumptions, and exterior conditions simplified to just a few inputs such as ground reflectance or standard obstructions.

Level Two contains higher level of detail, appropriate for demonstrating compliance with codes or standards at the completion of construction documents. Logically, the input details and assumptions at this phase should be verifiable from construction documents and an approved calculation methodology. For these purposes, Level Two should generally make pessimistic assumptions about interior furnishing and operating schedules using defaults to define a minimally acceptable condition that is likely to be maintained in typical, rather than idealized operating conditions. Window details should be three dimensional to include inter-reflections and shelf-shading from framing elements. Operating schedules, window treatments and obstructions should follow standardized rules to avoid gaming.

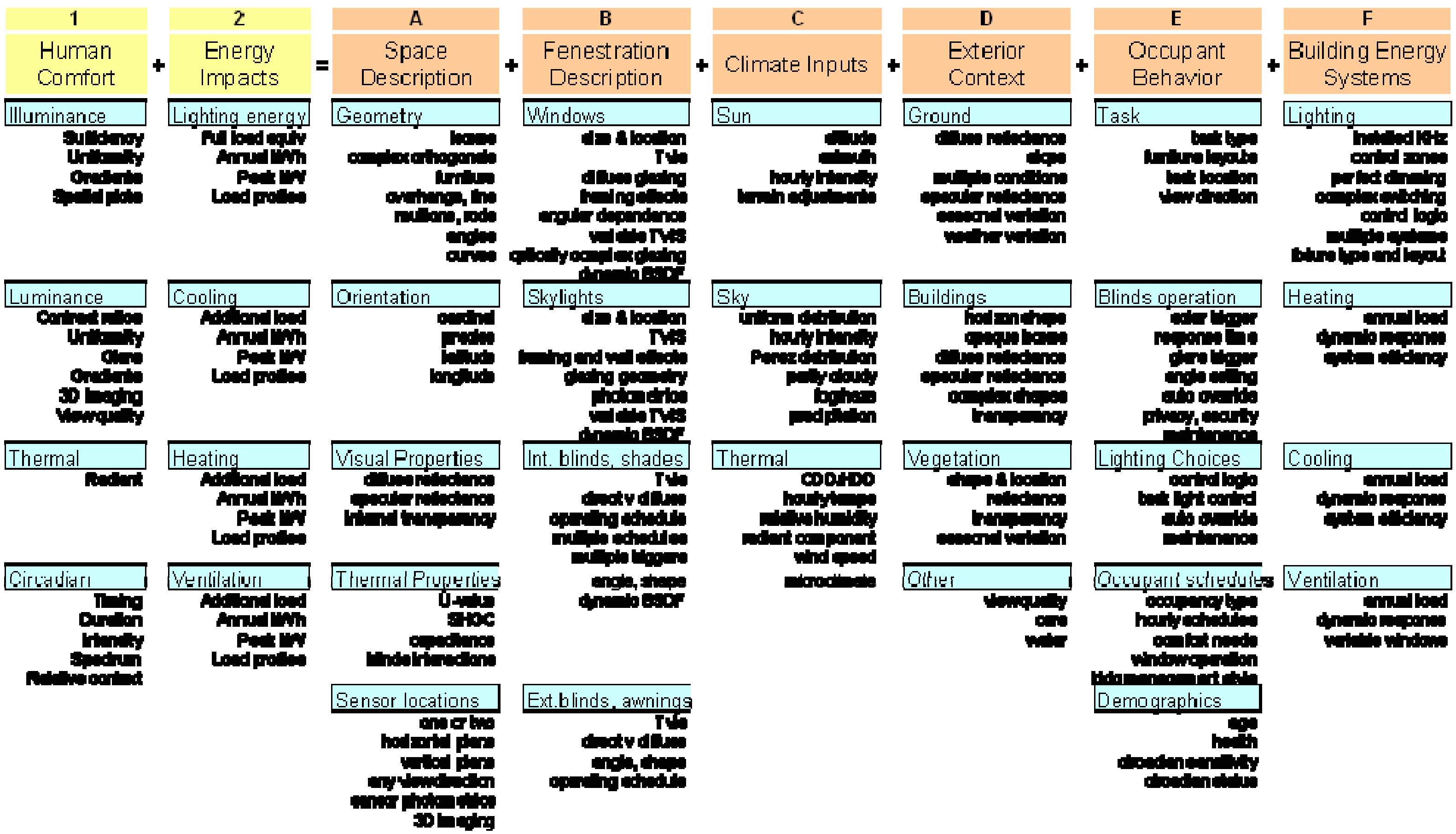
Level Three contains the greatest simulation detail, appropriate for modeling existing buildings for research or verification purposes, where actual furniture layouts, window treatments, surface colors, operating schedules and exterior obstructions are known. This level includes measured data, where available, such as surface reflectance and operating schedules, or level two defaults when not available. Exterior details should be fully modeled, including vegetation. The goal of level three is to provide as realistic a comparison as possible to actual occupant experience. Logically, for field verification, comparable results should be derivable from both simulation input and field data, such as monitored illuminance levels or photographic luminance capture techniques. Because analysis at this level is most interested in realistic models, research-grade simulation tools that favor accuracy over ease-of-use simplifications would be most appropriate.

1.3.3 Daylighting Analysis Framework

Given the range of needs described above, it is useful to envision the scope of a future comprehensive daylighting analysis capability. illustrates the range of issues that might be considered in such an idealized analysis of daylighting performance. This idealized framework can:

- Help guide thinking in terms of what kind of daylight performance metrics are desirable versus those that are feasible, given current simulation capabilities.
- Clarify the conversation about what information is necessary for which purposes, and the priorities for developing the tools that are needed to support those needs.
- Clarify the differences between these simulation programs, or how two programs might be complementary.
- Help define the minimum capability requirements for a code compliance tool, or energy efficiency program needs.

Figure 1 A Daylighting Analysis Framework



The Daylighting Analysis Framework presented in Figure 1 allows comparison between the output of different program needs, the capabilities of tools, and the input data and analysis levels required to support them.

The framework in is organized like an equation, with outcomes on the left and inputs on the right. **Outcomes** of interest, shown on the left of the equation, are grouped into two columns: (1) Human Comfort issues and (2) Energy Impacts. Under Energy Impacts, the four concerns are logically Lighting Energy, Cooling Energy, Heating Energy and Ventilation Energy. Under each of these subtopics, examples of various types of metrics or data are listed in approximate order of detail, complexity and significance. More detail could be generated for the topic introduced within each cell.

Inputs include a comprehensive list of determinants of daylighting performance as well as influences on the other outputs, including:

1. a thorough description of the three dimensional space,
2. description of fenestration geometry, properties and operation,
3. local climate data,
4. the exterior context that influences the availability of daylight in the space, such as exterior obstructions,
5. occupant descriptors, including tasks determining illumination needs and operating schedules, and
6. interactions with other building systems.

As in the Outcomes discussion above, each cell lists additional data input descriptors, from the simplest format to increasingly detailed and nuanced. For example, under Space Description/Geometry the simplest analysis approach might be limited to simple boxes, whereas more sophisticated analysis could include complex orthogonal shapes, details of window overhangs, fins, mullions, and angled and curved room shapes.

An idealized simulation tool based on this framework would answer any question designer or researchers might choose to ask and consider every significant variable with appropriate precision, while providing an intuitive user interface and instantaneous results. We are, of course, far from having such comprehensive simulation capabilities.

However, this idealized framework proved useful in evaluating the capabilities of different simulation programs and matching output to user needs. Other filtered versions of the framework are included in Appendix C to illustrate the project team's assessment of the then current capabilities of various simulation programs, and perhaps most usefully, to illustrate the final set of inputs and outputs considered in the analysis of this project. These are NOT intended as definitive documents for references, but rather as aides in focusing discussion about simulation capabilities and needs.

1.4 Research Plan

Given the overall goals of the committee, a research plan was formulated to make as much progress as possible within a three year time frame. The general outlines of that research plan defined the scope of work for this project, conceived in support of the committee's goals. The definition of specific strategies and tasks were always considered relative to project resource constraints. The basic components of the research plan are listed below, along with the key consequences for the research plan.

- Qualitative assessment of real spaces by both experts and occupants
  - Thus, the need for a field study
  - Focus on three critical space types
  - Selection of study spaces for diversity of daylighting conditions
- Climate-based daylight simulation of those spaces to generate annual performance data representative of the space as experienced
  - Thus, the need for advanced daylight simulation capabilities
  - Selection of three output illuminance sensor grids
  - Focus on improving blinds simulation capability
- Processing of the simulation output into a variety of candidate metrics for comparison to the qualitative assessments
  - Thus, the need for distillation of large data sets into manageable variables
  - Selection of metric types for study
  - Use of multi-level regression analysis for quantitative analysis
- Selection of preferred metrics by the committee, given an understanding of precision, utility, ease of generation, and ease of use
  - Thus, the need for guidance and oversight by the range of experts on the committee
  - Thus, the need for meaningful visualization of simulation output

Each of these components and its impact on the research plan is discussed in more detail below.

1.4.1 Need for a Field Study

Since the key goal of this project was the development of daylighting performance metrics applicable to real world buildings, it was decided early on that a field study of real daylit spaces would be a fundamental component of the study for a variety of reasons:

- To compare across expert evaluations of those spaces, to work towards a national and international consensus of what constitutes a "well-daylit space"
- To compare between expert and occupant evaluations of those spaces, to make sure that occupant needs and perceptions were truly being addressed
- To assess the range of conditions that must be accounted for in real world spaces
- To challenge the capabilities of both the simulation tools and the resulting metrics to make sure that they could accommodate the range of conditions found in real spaces.
- To compare the output of simulations to real world experience.

In support of these goals, a field study was planned that would send a small troupe of experts around to a variety of daylit spaces so where they could use that shared experience to discuss and evaluate the positive and negative qualities of those spaces, bridging across regional experience and educational biases. to ultimately reach consensus, it was very important for the group of daylighting experts to have a set of shared experiences that could be used for common reference, so that they could agree that the metrics were capable of providing a fair and equitable measure of the daylighting performance of the range of spaces considered.

A field study of real spaces also gave the project the opportunity to compare between experts' and occupants' experiences of the spaces, even though they were unlikely to occur under identical conditions. Very often expert opinions are criticized as overly sensitive, or alternatively, insensitive, to the actual experience of occupants. Furthermore, occupants experience a space for much longer and under a wider range of conditions than a visiting expert, and thus may be better integrator across all weather conditions and task needs. The challenge, then, would be to find a standardized method that could usefully compare the assessment of the experts, described in a highly specialized professional language, and that of the occupants, using only vague or vernacular descriptions of their personal experience.

To focus the field study within project resource constraints it was agreed to select a subset of commercial space types that were most in need of daylight performance guidance. Three space types were selected (discussed in Section 2.1.1) and these study spaces would then also form the basis of the simulation analysis.

1.4.2 Simulation Capability Needs

The goal of the simulations was to use three dimensional computer models to predict annual daylighting conditions in the study spaces over the course of a full year, as closely as possible modeling the experience of the occupants. While the use of actual weather information might have allowed the tightest calibration of the computer models to real experience, the use of typical weather year (TMY) information was considered closer to the type of professional practice that would actually be used to generate metrics. Thus, one of the most important criteria of the selected simulation tools is that they be able to use TMY weather data for all 6780 hours of the year.

In addition to the employment of TMY weather data, there was also a goal to find simulation tools that could successfully model the wide variety of fenestration types, orientations and daylight control strategies found in the field, and their dynamic operation to maintain occupant comfort under changing weather conditions. The most common, and yet most challenging, of these would be simplest manual operation of window blinds and shades.

While it was considered important to find simulation tools that could model the complexities of three dimensional spaces found in real world spaces, such as angles and curves, other complexities, such as seasonal variation in vegetation or ground cover, were ignored for the sake of simplicity or lack of sufficient information. The final simulation capabilities and assumptions are summarized in Appendix 0.

Ideally, a simulation tool would be capable of creating a "virtual reality" output that would closely approximate real occupant experience and yet could be measured and distilled down into unitary metrics. Given the limitations of current tools, it was agreed early on that illuminance output at three sensor grids would be the highest level of output that could be expected from current simulation tools.

It is clear that the development of new performance metrics for daylighting must be an iterative process between understanding needs and tool development. Understanding organizational needs of all likely users should help to define the functional requirements for simulation tools, but the current capabilities of simulation tools also set both expectations and limits on what metrics can be considered.

1.4.3 Testing Candidate Metrics

The data collected from the field study, and the subsequent simulations would then be combined into an analysis method to compare the qualitative assessments of the experts and occupants to the quantitative output of the simulations. Multivariate linear regression analysis was the preferred analysis tool, although other statistical methods could also be employed. The goal was to be able to test a variety of metrics against the qualitative assessments, to see which could most successfully predict the experts' and occupants' assessment of daylight sufficiency or daylight quality.

The findings of the statistical analysis would then be used to help inform the discussions of the IES DMC in proposing a suite of annual performance metrics that could meet all of the user needs discussed above, such as:

- a standardized methodology, within reach of the average practitioner
- a useful format for codes and standards, with adjustable acceptance criteria
- an intuitively understood construct

- with acceptable precision
- to provide successful guidance for building and product designs and specifications.

CHAPTER 2:
Data Collection

Chapter 3 describes the methodology used to collect and analyze the field study data, and the sequence of decisions made along the way to address challenges encountered. This chapter is focuses first on the determination of the study sample and methods of data collection both about the site itself, and then on the qualitative assessment its daylight characteristics by occupants and experts. It then describes the simulation metrology used to generate annual daylighting performance data that could be compared to the qualitative assessments.

2.1 Study Sample

Selection of appropriate spaces to study that could best inform the development of a suite of metrics was the first major task of the project. A balance needed to be achieved between realistic time frames and budgets, and the desire to have as broad and representative sample as possible. The task was further complicated by the lack of a definition of "daylit spaces" or information on how to identify the characteristics of the larger population that should be represented.

Given the goal of national consensus on the metrics, it was important to include a variety of climates and building types in the study. This goal was facilitated by funding from a number of sources, which enabled the project to include buildings across three locations in California, two in New York State, and one in Washington state, for a total of six climate conditions. A variety of urban and suburban building types, and a range of architectural styles and vintages, were also included.

2.1.1 Space Types

As mentioned earlier, the IES DMC and the project team agreed to focus their efforts on three key space types: classrooms, open offices, and library-type spaces. These three space types are commonly targeted for daylighting, provide important energy saving opportunities, and encompass a range of visual tasks and quality issues that need to be addressed. For purposes of this research, these space types were operationally defined by describing their use characteristics and therefore the findings can be generalized to any space with reasonably similar use characteristics.

The IES DMC formally defined the three space types:

7. **'Office' space type**: Regular occupants have fixed desk location with a fixed orientation, primarily computer, phone, paper based tasks plus one-on-one conversation

8. **'Classroom' space type**: Regular occupants likely have assigned seating locations, with multiple task orientations, including towards "front of classroom," group discussions, and desk work.

9. **'Other' space type**: (a.k.a. Library/Lobby) Occasional occupants actively move through space, looking at displays or shelving, and/or may choose a preferred work location, including tables, easy chair, or counter.

The Office type is quite straight forward, and is intended to include both private and open office spaces. The study focused on open offices for two reasons: first, because open office spaces provided a larger population of occupants for the study, and secondly, because they presents a more important concern for daylighting visual quality and energy balance. In contrast, private offices, with only one or two occupants are more easily controlled to the occupant's preferences via manual controls, and occupancy sensors generally provide most of the cost effective savings from photo-controls.

The Classroom type was interpreted to include conference rooms, in addition to most educational classrooms from pre-school through high school and college and adult education. However, special purpose classrooms, such as computer instruction, auditoriums, or science labs should likely be excluded from this type.

The Other type, was interpreted to include library reading and work areas, lobby areas, and multi-purpose rooms. In might also include transportation lobbies and service desks, banking areas, and other large open public spaces with a mix of task types and the ability of occupants to choose their preferred location. However, given security and access concerns in banks and transportation facilities, the study focused on libraries and lobbies where the project team was most likely to be given permission for sustained access for the survey work.

2.1.2 Sample Frame

The study plan laid out a goal to identify and study approximately 20 spaces of each of these three types, and no less than 18. This number was considered the minimum that was likely to be able to provide statistical significance in the final analysis.

Based on the three space types, the geographical areas funded by the study, budget limitations, and the need for as much analysis precision as possible, a sample frame was drawn up for the study goals, shown in Figure 2 below.

Figure 2: Sample Frame Goals

	California	Washington	New York	Total
Classroom	12	6	2	**20**
Office	12	6	2	**20**
Library	12	6	2	**20**
Total	**36**	**18**	**6**	**60**

In addition to these space type and geographic goals, it was agreed that the project needed to find a diversity of orientations and daylighting strategies, from the obviously good to the obviously bad, in terms of both daylight illuminance levels and daylight visual quality, with the majority somewhere in between. The goal was to achieve a wide range of daylight strategies, from toplit to sidelit, from highly sophisticated to very basic design approaches.

to maximize the efficiency of the site visits, it was agreed that up to four spaces within a given building could be included if they offered a variety of orientations, spatial configurations, daylighting strategies, and/or space types. For example, at one school site study spaces could include an office, a library, and both a top lit classroom and a sidelit classroom, or one south facing and one north facing classroom. Or at a public library, an office, a classroom and a library reading area could all be studied.

However, it was decided that to maximize diversity, that the study should average no more than two spaces per building, and avoid multiple building sites by the same architect or design team.

2.2 Site Selection

After the sample frame was drawn up, team members and daylighting experts in each region were contacted to nominate a variety of spaces that would meet the criteria and likely be accessible for study within the project time frame.

Each building was researched for its fit within the sample frame and selection criteria, daylight strategies, and accessibility to determine its suitability for the study. For example, 24 buildings were nominated in New York State, 9 were visited by the experts, and 6 were ultimately selected for final study.

A schedule was drawn up to take the project team and invited troupe of experts to visit the candidate spaces over two weeks in July and one week in August, 2007.

2.2.1 Selection of 61 Study Spaces

The team ultimately visited 77 candidate spaces over the course of five days in California (Sacramento, San Francisco, Truckee), two days in Washington (Seattle Metro area) and three days in New York (Albany, New York City). From this initial group of 77 spaces, the study sample was reduced to 61 sites used in the analysis.

A space was removed if 1) it was determined to be too irregular to represent the operational definitions of the three space types described above, 2) there was insufficient access to conduct the second site visit, 3) permission to survey occupants was denied, 4.) it was likely to be reconfigured over the course of the study, or 5) it was too geometrically complex to be accurately simulated with currently available simulation tools.

The final study sample, shown in Figure 3 successfully captured a good range of daylit spaces with different daylighting strategies. With 28 buildings represented, the sample averaged 2.2 spaces per building.

Figure 3 : Final Study Sample

	California	Washington	New York	**Total**
Classroom	13	4	5	**22**
Office	11	7	5	**23**
Library	9	6	1	**16**
Total	**33**	**17**	**11**	**61**

The 'Office' category included 12 in public sector workplaces, and 11 in private sector. The smallest study area was a two person office, but typically they included 9-12 cubicles, with the largest having 18 occupants.

The 'Other' (Library/Lobby) category included: 5 school libraries, 4 public libraries, 1 private library,4 lobbies, and 2 multipurpose rooms.

The 'Classroom' category included: 2 classrooms in preschool, 8 in elementary schools, 4 in middle schools, 2 in high schools, 4 in college or adult education, and two conference rooms.

Study Space Descriptive Statistics

The sample had 12 spaces with skylights, 7 with light shelves on windows, 9 with clerestories, 4 with rooftop monitors. Out of the 61 spaces, 28 had windows in more than one orientation, 32 had windows in a single orientation, and 3 had no vertical fenestration, with daylighting only from skylights or roof monitors.

Of the 61 spaces, 26 percent faced primarily south, 10 percent having a combination of south and other orientation, 20 percent faced only north, 12 percent facing a combination of north and other orientation(s), 8 percent faced either east or west, with another 16 percent including some east or west orientations. 56 percent had some daylight aperture besides view windows, including the 8 percent which had a diffusing intermediary, like an atrium, and the 26 percent which had some form of toplighting, either monitors or skylights. These numbers do not add up to 100 percent because there were many overlapping conditions. The main point is that the final 61 study spaces represented a balanced range of orientations and daylight strategies, as originally intended.

Other interesting observation is that of these daylit spaces, 41 percent used a form of slated blind (horizontal or vertical), 36 percent used a form of roller shade, and 23 percent had no blinds. Most of the cases with no blinds also had no view windows and/or transparent glazing. Of the 10% of spaces with no blinds that did have view windows, all but one were so oriented or so shaded as to allow essentially no sun into the space. Thus, the field study found that occupant controlled blinds or shades are ubiquitous on vertical glass. Also, as will be described later from the occupant survey responses, the blinds and shades seem to be fairly actively managed within this study population.

The full list of the 61 one study spaces, with more descriptive summary information, is included in Appendix D.2. Because of confidentiality agreements, the spaces are identified only by their ID number, indicating general location, building and space number. Thus, 'SFO1.2' indicates the second space in the first building surveyed in the San Francisco area. In addition, Appendices D.2 and D.3 present interior photos and images of the three-dimensional models of each of the 61 spaces, along with simulation analysis results, to help readers gain more insight into the physical conditions of the study spaces.

2.3 Site Surveys

Information on the sites was collected during a number of site visits.

1. Pre-visit data collection: A preliminary site visit might have been made by one of the project team in the initial assessment, or for a previous project, to qualify the space as a candidate for the study. If the candidate space was under study for other purposes (such as previous design consulting in the case of the Integrated Design Lab, previous monitoring in the case of HMG, previous case studies in the case of some of the New York sites) as much existing data and images as possible was collected from pre-existing sources. In addition floor plans and weather data for that site were prepared to facilitate the next visit.

2. Expert Site Visit: The initial screening visit by the troupe of experts involved interviews with the building host, a tour of the building leading to selection of specific study spaces to best meet the sample frame goals, definition of the physical extent of each selected study space(s), documentation of current space conditions via photographs and illuminance readings, and expert assessments of the daylighting conditions. When possible, occupants were also recruited to fill out the occupant survey form. Each of these activities are described in greater detail below. Data were collected on 71 spaces at this stage. These were all done in July and August of 2007.

3. Surveyor Site Visit: After a space was selected for the final study group of 61 spaces, a surveyor returned to the space to collect detailed physical data to support the simulation modeling of the space, these were done between September and November of 2007.

4. Return Site Visit: Some spaces required a return visit by the surveyor to collect additional information, and/or recruit more occupants for the occupant assessment. These were generally done in November or December of 2007.

2.3.1 Space Definition

For each study space, the limits of the physical area used during the subjective assessments and for simulation were determined based on two criteria; to define a coherent daylit area that could be easily conveyed to occupants and subsequent surveyors, and one large enough to include at least 10 routine occupants who could be surveyed.

Space Size: For example, in the case of a classroom, the whole room was defined as the space, but in the case of a large open plan office, a representative area including 9-12 workstations was defined as the space. Typically these study spaces ranged from 600 sf to 2000 sf, with the average size 1287 sf. The average sizes, plus max and min, for final sample of three space types are shown below in Figure 4.

Figure 4: Square Footage of Study Spaces by Type

Space Type	Average Area sf	Maximum Area sf	Minimum Area sf
Classroom	768	986	352
Office	1459	2755	160
Library/Lobby	1750	3680	157

The definition of the study space was done during the expert visit and noted on a floor plan for future reference. For classrooms, conference rooms, small offices, and lobbies, this was generally an easy decision and involved the entire space to the full-height walls. A few study spaces were included that had glass partition walls within the space, since the goal was to capture a continuous daylit zone, rather than HVAC zones or privacy definitions.

In large spaces, where only a portion of the space was needed for the study, this process was more complex and subjective. Visible physical limits were identified where ever possible, such as columns, service counters, or cubical numbers. In general, the space definitions erred on the side of including the furthest limit of space that could possibly benefit from daylight illumination, since the project did not yet have an agreed upon definition of a 'daylit space.' In some of the larger spaces, with ample daylight from many directions or overhead, the space was logically segmented into an area that captured all the daylight influence from nearby apertures, and had a coherent task.

For study spaces that were part of a larger area, physical information was also collected about the adjacent spaces to include in the simulation model, to better model the inter-reflections within the larger space and any contributions from nearby fenestration. These were called 'contextual" spaces. The modeling rules for both the study spaces and the contextual spaces are explained in Section 2.5 and Appendix C.8.

Study Space versus Daylit Area: The issue of the definition of the "study space" became critical later in the analysis, since it had an important influence on the final simulation output, and hence analysis findings. There was not have the opportunity to revise the definitions of the study spaces after the fact, for example after better information about the limits of daylight availability in the space became available from simulations, and/or after definitions had been agreed upon of what should be considered "daylit area". Ideally, a second iteration of the study would go back and be able to focus data analysis more exclusively on only those areas that had comparable daylighting conditions, as subsequently defined by the accepted metrics. Such an effort could potentially be done with the existing data, or by applying the findings of this project to a new set of study spaces.

2.3.2 Site Data Collection Protocols

As mentioned earlier, the physical and operation characteristic for each site were collected in two passes: First, for all 71 candidate spaces during the expert visits (described below), and second, in more detailed later survey, for only those 61 spaced selected for inclusion in the study.

The first survey was conducted simultaneously with the experts visit, and documented the conditions at the experts visit and documented the space sufficiently for a second visit for more detailed physical descriptions. The standard protocol included information on the current weather including time stamps and sky photos, a matrix of hand held illuminance readings on walls and task surfaces, digital photographs taken from the corners of the room and HDR images taken in four orthogonal directions from the center of the space at standing eye level, and a physical description with a sketched plan to mark the limits of the study space. The data collection forms for this first survey are included in Appendix B.

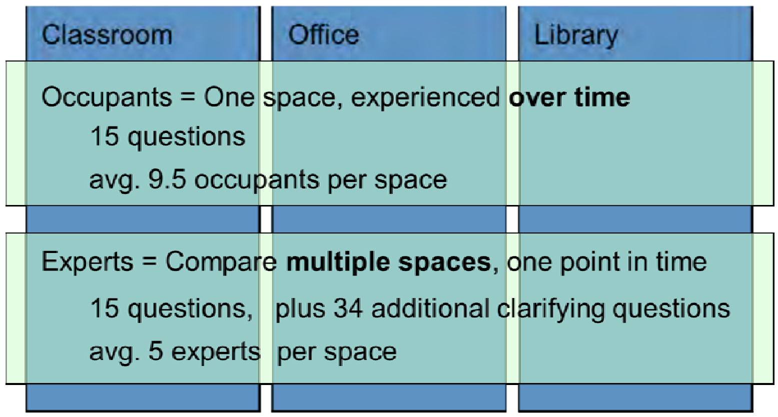
The second survey collected the information necessary to construct a detailed 3D computer model of the study space and its surrounds. In addition to the information described above, it also collected detailed measurements in plan, section, and especially window details such as sill and mullion dimensions. Information about the electric lighting system was collected, and measurements were made of the window VLT wherever possible, along with detailed observations of the blind type and settings. The site host was interviewed about building schedules and space occupants were interviewed about blinds operation. While HMG staff performed the second pass surveys in California, subcontractors were given a training course trained to collect equivalent data in Seattle and New York. The data collection forms for the second pass survey are included in Appendix A.3.

The on-site survey data was transferred to the modeling team directly via PDFs of the survey documents. The modeling team used the forms, photos and any available plans to construct their models. On-line aerial images, such as from Google Earth, were also used to confirm orientation and obstructions. The site survey information has been preserved if needed for future study.

2.4 Expert and Occupant Surveys

Early on in the project, the project team determined that two types of survey data would be needed to capture the variability of daylight over time and across the three space types. This need was resolved by the approach of collecting daylight quality assessments, using comparable formats, from both routine occupants who experienced each space over time, and specially selected experts, who could compare across spaces but who had very short time exposure to the space. This concept is illustrated in figure 5 below.

Figure 5 : Conceptual Diagram of Site Data Structure



It was reasoned that "experts", such as professionals trained in architectural daylighting techniques, climate data and analysis, could provide in depth assessment of each space, calibrating their experience across a number of spaces, and among each other. Occupants were likely to have a more naive experience of the space, with limited understanding of lighting jargon or the goals of good daylighting design, but with a experiential understanding of what they liked and what problems they experienced over time. Together, they could provide a more comprehensive assessment of the study sample.

Experts Provided Depth of Understanding and Continuity across Spaces: One larger goal of the project was to help develop professional consensus on how to define 'good daylighting". Thus an important objective was to bring as many "daylighting experts" together as possible to experience and evaluate spaces simultaneously, under the same daylighting conditions, so that they could develop a larger common set of experiences to discuss and compare. A few of the experts were likely to have studied individual spaces nearby to their home location or for which they had served as consultants, and thus have developed an understanding of the performance of those spaces across time. However, given the realities of budgets and scheduling field visits, it was understood that the experts would only be able to visit each space once, for a brief site visit, thus limiting their experiential understanding of the space.

The study spaces were evaluated variously by a subset of 18 invited experts, for a total of 324 expert assessments for the 61 selected spaces. (Since the experts actually visited all 71 candidate spaces, there were a far greater number of expert surveys collected overall.) As shown in Figure 6, an average of 5.3 experts visited each space, with up to eight experts for the most and three for the least. The experts were solicited from a well-known group of educators, researchers and practitioners active in daylighting. All members of the IES DMC were invited to participate when feasible. Members of the project team were paid to travel to the study sites. Others needed to volunteer their time. In addition, some local practitioners were included in Seattle and New York to ensure a local perspective.

Figure 6 : Expert Responses, by Space Type, for 61 Spaces

	Total	Avg per space
Classroom	113	5.1
Office	128	5.6
Library/Lobby	83	5.2
Total	324	5.3

The 8 experts employed on the project team each visited an average of 42 spaces of the 61 selected study spaces, with three members of the team visiting essentially all the spaces; the 10 experts specifically on the IES committee each visited an average of 29 spaces, or about ½ of the spaces, and the group of 18 experts overall, including some local visitors who only visited two or four spaces, averaged 22 spaces each. Thus, the objective of developing a common set of experiences across the group of experts was achieved.

The experts who participated in these evaluations, and the number of spaces they evaluated, are listed in Appendix 0.

Occupants Provided Direct Experience and Continuity across Time: it was also understood that occupants are the real "client" for a daylit space, and thus their assessment of the performance of the space was the real touch stone. However, there were a number of potential complications of administering a daylight quality evaluation survey instrument to the actual occupants of the study spaces:

- Access: there was no certainty that the project team would be given permission to survey occupants in all of the study spaces. The expert assessments thus provided a fallback if no occupant assessments were available.
- Language: it was unknown if the same questions were asked of experts and occupants if they would have comparable understanding of the questions, given occupants' potentially "naive" interpretation of lighting jargon
- Location: there was no reliable means to locate occupants within the space, or understand their primary view direction. Furthermore, confidentiality required that the occupants' responses be kept anonymous, which also meant that they could not located retroactively.
- Timing: given the shear difficulty of collecting sufficient occupant assessments for statistical analysis, it was not possible to also constrain WHEN they filled out the survey or under what daylighting conditions. The survey did ask occupants how much time they spent in the space, and over what time period, but the survey recruitment methods could not guarantee that respondents had a well-

rounded experience of the space, or that their responses would reflect the average of the year, rather than their most recent experiences.

To address these concerns, as many occupant surveys as possible were collected for each space. This required great persistence on the part of the project surveyors, with repeated requests to a few of the last spaces. The occupant recruitment methods, and descriptive statistics of the final sample are discussed in Section 2.4.3.

2.4.1 Survey Instrument Development

The core project team gathered in the offices of HMG in Sacramento for practice and refinement in using the survey protocols. An initial survey instrument was developed and tested on two offices HMG the first day, and then based on discussion of common understanding among the group, revised and refined for further practice on the second day. The occupant version of the survey was tested on a number of naive subjects for verification that the language was easily and consistently understood. The second day the group went to a nearby library and school for further testing and refinement of the expert survey protocols. With that experience, the survey instrument and instructions were finalized and conveyed to subsequent experts who joined the tour of candidate spaces in various cities, and the occupant surveys were prepared for distribution to occupants.

The occupant questionnaires were simple and only one page, with a few standardized-response questions on the front and 4 open-ended memo questions on the back. The front included 7 demographic and spatial characteristics check box items, and 15 qualitative questions to be graded on a 9-point Likert scale. The Likert-scaled items addressed the occupant's assessment of room aesthetics, thermal comfort, acoustics, view quality, view quantity, satisfaction with blinds, electric lighting sufficiency, daylight sufficiency, daylight excessiveness, and visual comfort (glare).

The expert questionnaire was more in depth, at four pages. The expert questionnaires began with the same 15 Likert-scale questions given to the occupants, plus another 40 probing more specifics on visual comfort (glare), daylight uniformity, visual interest, personal control, and visual and acoustic privacy. Space was also provided for free-form observations.

The Expert and Occupant Survey Forms are included in Appendix A.

2.4.2 Expert Assessment Protocol

All of the expert visits were made during July or August of 2007, typically for 1-2 hours per space. Observations were made between 9 am and 5 pm, with the median time at 12:52 PM daylight savings time, for example solar noon. Climate conditions were recorded at the time of the visit, with almost all under sunny or partially sunny conditions. There were no foggy, heavy overcast, or rainy days.

At each new site, experts were given descriptions of the local climate, and asked to imagine the sun path, given the latitude and orientation and exterior obstructions. They were asked to sit in a variety of conditions in the defined study space, and give an assessment that they felt would be representative of the average occupant experience of the space. This did require an "educated guess", informed by the experts' experience in many other spaces and educated knowledge of solar positions and weather variation.

The experts were asked to evaluate the space silently, and only discuss their experience after fully evaluating each study space within a given building. They initially expected to have very different understanding of the visual quality within the spaces, and often had animated discussions after each visit. However, subsequent comparison of the expert survey forms found closer agreement than expected (see Section 3.1). Any obvious outliers were discussed at the end of each day for possible misinterpretation of the question.

2.4.3 Electric Lights

The expert team typically went into candidate spaces that were occupied, during normal working hours, and thus they first experienced the space with the electric lights turned on. Whenever possible, permission was obtained to turn the electric lights off for at least a brief period to enable evaluation and photography under daylit-only conditions. For most spaces, especially those that were well daylit, this request did not greatly inconvenience the occupants, and thus was often continued for ½ hour or more. For a few spaces, especially those with poorly daylit portions, the time under only daylit conditions was minimized to about ten minutes.

Observing occupant reactions to switching off the electric lights was a very interesting anthropological experiment. In one library, where the librarians had been very hesitant to allow the lights to be turned off, they were finally persuaded to pretend it was only a brief "power outage". When not one of the library patrons complained, or even looked up, the librarians realized the adequacy of the daylight in that space. In a few well daylit offices, after the portion of the study with the electric lights turned off was completed, occupants asked the project team to leave them off. However, since management had been promised that the space would be returned to the as-found condition, the lights back on upon leaving.

Some spaces were visited outside of normal operating hours to allow more latitude in studying the space under natural daylight conditions. This was especially true of the school classrooms, which are generally un-occupied during the summer months. Such unoccupied spaces were first observed under daylight only conditions, and then operated the electric lights to understand their control logic and also experience the space under fully illuminated conditions.

2.4.4 Blinds Operation

Likewise, for occupied spaces, the blinds were observed at the setting maintained by the occupants. Where feasible, the study team asked for permission to modulate the blinds settings to observe the effect on interior illumination patterns. For un-occupied spaces, the space was first observed with the blinds set as found, unless they were fully closed, in which case they were opened. Upon leaving the space, the blinds were returned to the position found on entering the room.

2.4.5 Expert Subjective Impressions

In addition to the quantitative portion of the survey, the experts were also given a page to freely their impressions and non-standardized descriptions of the spaces. It was assumed that such free-form observations might be useful in subsequent interpretation of the data. These have been preserved for future review, if needed.

It was important that the troupe of experts included a range of geographic and climatic expertise, so that it was not biased by, for example, an 'east coast" or "west coast" perspective, or practitioner versus educator. Informal observations did note two groupings of experts with inherent differences, which might seem rather obvious in retrospect: 1.) those experts working mostly in dense urban areas had much more forgiving standards for "view quality" and 2.) there were generational differences in the confidence of experts in doing field evaluations, with the older set more confident in imagining spaces over time, while the younger set stated they felt most confident limiting their evaluations to the current conditions.

2.4.6 Occupant Assessment Protocol

Recruitment: Participation in the survey was voluntary for all respondents. Permission was secured from the building management before approaching any occupants to ask if they would fill out a survey form.

In the office spaces, occupant surveys were collected from the occupants of cubicles only within the defined study space. There was close to 100 percent response for these spaces.

In classrooms, both teachers and students were asked to fill out survey forms. In elementary schools, for very young children, sometimes this was by a show of hands to oral questions, rather than filling out the form. For preschools, only the staff participated. For adult education and conference rooms, a number of frequent users were surveyed.

In library and lobbies, any user in the study area was approached and asked if they would fill out a survey. Typically, at least one or two permanent residents of the space, such as librarians or lobby attendants also filled out a form. For those classrooms or libraries with very low respondent numbers, typically it was only the teacher or the librarian who responded, if for some reason the study team was not given permission to approach other occupants.

The final number of completed surveys by each space type is shown in Figure 7 below. With a final count of 584 independent occupant responses of daylit spaces, the goal of an average of 10 occupants per space was nearly reached.

Figure 7 : Occupant Responses by Space Type

	Total	Avg	Min	Max
Classroom	288	13.1	0	30
Office	170	7.4	1	18
Library/Lobby	126	7.9	0	19
Total	584	9.6		

A few building sites initially agreed to participate in the surveys, and then declined after they had been accepted into the study. The decision was made to keep those few spaces with zero or very few occupant responses in the study to preserve the range of space types. The methodology of using both expert and occupant assessments provided the mathematical ability to use these spaces in the regression equations.

Occupant biases: It is clear from the distribution of responses that classrooms, which had the highest response rate, might also be expected to show higher statistical significance. Also, given that the data set included ten elementary school classrooms, and two each high school and middle school classrooms, it is understandable that the average age of classroom occupants was much younger than for the other two space types. Given known age-related differences in visual preferences, the age variation might also be expected to influence the study findings. There are no other known biases in the occupant population.

2.4.7 Occupant Demographics:

The survey instrument collected information about the occupants, and the conditions during which they filled out the survey to assess if there were any strange distortions in the sample. The following information about the respondents is reassuring that the study population was within the expected norms:

- The average occupant responding was 29 years old, with a range from 7 to 79.
- Answering the question "How long have you been using this room?" the majority, 64 percent, had been using the room for 5 months or more:

4%	Just Today
2%	A week
4%	A month
26%	2-4 months
22%	5-11 months
42%	A year or more

- Answering the question "How many hours do you generally spend in this space?" The majority, 63 percent, were there for 5 or more a day.

17%	An hour or less
30%	2-4 hours
18%	5-7 hours
35%	8 or more hours per day

- Answering the question "If this room has blinds or curtains, overall right now they are:" Only 35 percent reported that the windows were ½ or more covered, while 65 percent reported that the windows ¼ or less covered.

20%	Fully closed
7%	¾ closed
9%	½ closed
16%	¼ closed
31%	Fully open
18%	None in space

- Answering the question "how close are you to a window with a view?" The majority, 53 percent, were within 15 feet of a window.

20%	About 5 feet from the window
33%	10-15 feet from the window
24%	20-30 feet (or more)
8%	No view from where I work
2%	Not applicable

- The weather conditions at the time of survey were fairly evenly distributed across the options offered, with 46 percent reporting light to heavy overcast and 51 percent reporting a clear sunny day. Notably, 22 percent of the occupants reported that they could see patches of sunlight <u>inside</u> of their rooms. This is consistent with the report that 65 percent of the blinds were mostly or fully open.

20%	It is a foggy day
13%	It is a lightly overcast day
12%	It is a dark overcast day (and/or with rain or snow)
22%	I can see patches of sunlight inside of this room
16%	I can see patches of sunlight, but only outside of this room

14%	It's a clear blue day, but I can't see any direct sunlight
3%	It is variable, with big clouds moving by and occasional sun

2.4.8 Data Entry

The expert and occupant assessment data was entered into a data base. The number of responses in each space was compared to data collection records to verify complete data entry. Descriptive statistics were reviewed to verify that all data were within expected ranges, and were distributed in a consistent fashion. Any outliers were identified and reported to team for further investigation. When needed, the second pass surveyors (described below) were tasked with clarifying information or collecting additional surveys to fill in data holes.

2.5 Simulation methodology

A key project goal was to be able to compare the expert and occupant assessments to metrics generated from annual simulation data, which accounted for local weather conditions and the specifics of the space as occupied, modeling each of the 61 spaces as accurately as possible, or at the very least, accounting for the major influences on daylight availability in that space. A second important goal was to be able to compare outcomes across the whole study population, which required consistency in operating assumptions. This set of goals set the project team on a quest to first identify, and then ultimately to develop, software tools that were capable of modeling real spaces with sufficient realism.

During the process, the limitations of many software tools were identified in great detail. The Daylighting Analysis Framework, described earlier in Section 1.3.3, was used to help track the capabilities of different software tools.

Given the need to compare results across spaces, it was essential to establish consistent operating assumptions, both for the period of analysis and for operation of any blinds or shades. These two key assumptions were:

- Operating schedule for the spaces were set to a standard 10 hour day
- Blinds operation were based on a solar trigger, by orientation and window group

Thus, the choices and development of the simulation methodology became an iterative process, trying to strike a balance between project goals and the capabilities of available software. Since the magnitude of the selection of various simulation details on the outcome of the daylighting performance was initially unknown, the project team tended to err on the side of providing as much detail as possible. The assumption was that information could always be backed down to more generic defaults if it were found to be non-critical to the outcome. Some sites were dropped early on to avoid challenges that were considered outside of the competence of currently available software, for example, optically complex glazing or daylight re-directing specular surfaces.

The discussion below first reviews the initial process of software selection, the requirements for simulation output, the decision to develop the Dynamic Radiance approach, and the format of final simulation output. Further details on modeling protocols are described in Appendix C.

2.5.1 Software Tool Selection

Based on an assessment of the simulation tools available at the beginning of the study, it was determined that using a combination of Ecotect to generate three dimensional models and Daysim to perform the annual simulations as a pre- and post-processor to Radiance, would provide the most modeling accuracy and support any parametric studies that might be determined to be important to the project goals.

Ecotect Version 5.5 developed by Andrew Marsh of SquareOne was selected to generate the 3D geometry files for use with Radiance because at the time, it was the simplest mechanism to create detailed Radiance input files. Daysim was initially selected to generate the annual simulation runs in Radiance, using the daylight coefficient approach. This allowed annual (8,760 hrs) simulations of daylighting using a TMY2 weather file for a location, and hourly reports of illuminance levels at various sensor grids within the space models. A private research-grade version of Daysim was modified by its author and project team member, Christoph Reinhart, to provide the output requested by the project team, including the potential for parametric studies. A description of Daysim and its daylight coefficient approach to annual daylight simulation are described in [Bourgeois 2008]. The process of evaluating options and selecting the initial software is described more thoroughly in the Software Selection Report included in Appendix C.1.

2.5.2 3D Model Development

The three dimensional models for importation into Radiance were constructed in Ecotect by a small team of graduate assistants at the Integrated Design Lab in Seattle, led by Chris Meek. Christoph Reinhart provided an instruction manual and training over the phone to ensure consistent interpretation. Having all of the models done at a single location, by a tightly coordinated team, also increased the uniformity of the modeling techniques used in the project, with the intention of reducing the natural variability in modeling techniques that would naturally occur among practitioners. The Ecotect modeling instruction manual is called the Daysim File Preparation Process and included in the Appendix C.

Each completed Ecotect model was then reviewed by Mudit Saxena at HMG for consistency with the survey data, site photographs to ensure consistency in technique between models. Once approved, the data from the Ecotect model was exported in layers into the Radiance format for processing in Daysim.

2.5.3 Simulation Output

Three requests for simulation output drove much of the 3D modeling process and subsequent analysis: the desire for multiple levels of analysis, for multiple sensor grids for illumination output, and preservation of hourly data by sensor, as described below:

2.5.4 Levels of Analysis

A key early decision in the modeling methodology was to define the opportunity for three levels of analysis that would satisfy a variety of user needs for daylight metrics, as discussed in Section 1.3.2. The general premise was to develop standardized simulation procedures for schematic design (Level 1), codes and standards compliance (Level 2), and research purposes (Level 3). Level 3 simulation procedures were used for all analyses in this project, and form the basis of the findings.

The 3D models in Ecotect were created using "layers" that would allow for different levels of analysis, from Level 1 through 3. For example, it maintained the ability to create models with standard IES default reflectance values for surfaces, or actual measured reflectances from the site surveys. The goal was eventually to be able to calibrate the difference in values for the calculated daylight metrics depending on the level of analysis. However, for this project, simulations were only run at a modified version of Level 3, and all of the subsequent analysis is based on that high level of detail.

The three levels of analysis are further described in Appendix D. The assumptions, granularity of detail, and various defaults included in the 3D models used in the analysis are described in Appendix C.8.

2.5.5 Sensor Grids

As described earlier, the research aimed to address three primary constructs of daylight within a space; 1) daylight sufficiency, 2) daylight excessiveness, and 3) daylight quality, as best as possible, given the current capability of the available software.

Early on it was determined that the project should be limited to analyzing illumination output from continuous sensor grids, and not attempt to process luminance data or metrics dependent upon 3D visualization capabilities of Radiance, which are extremely computationally intensive. Furthermore, w*hile commonly recognized glare metrics have been developed for electric lighting conditions, their application to daylighting conditions is highly controversial. All current glare metrics not only require luminance values but also a defined occupant view-point, which was inconsistent with the requirement for metrics that could universally compare any across all designs.*

However, given the limitation of illuminance-only output, there was still a desire to push that capability as far as possible in being able to inform the three concerns above. Thus, in support of these goals, the project team decided that the following three horizontal illuminance grids could potentially give useful output data for suite of metrics, as described below:

Task Level: A continuous grid of illuminance sensors with one foot spacing, looking upward, was located 32" above the finish floor (AFF). Using this height avoided most low furniture such as tables and chairs from impeding daylight penetration but included the influence of partial height walls or tall office partitions. Any of the data points that were "captured" inside the thickness of taller furniture reported very close to zero illuminance and were mathematically eliminated from the analysis. These data were used to consider 'daylight sufficiency', 'daylight excessiveness' and potentially 'daylight quality'. These values were generated for two conditions, 'blinds open' and 'blinds closed', and then compiled per an hourly schedule to produce 'blinds operated' values.

Eye Level: A second continuous grid was set at a seated eye level position (48" AFF). The sensor grid was then offset by 12" along the perimeter of the study space to simulate only those areas where a seated observer could occur. The goal was to have this grid generate data that could be used as glare proxies, to address the 'daylight quality' concern. Output from these sensors was used to calculate 'sun penetration' to provide a trigger for blinds operation and along with 'sky view', for example various descriptions of how much sun and how much sky could be visible to a seated observer throughout the space.

Ceiling Level: A third grid was located at the highest continuous horizontal plane that could be located in the space. This grid was oriented to look downward, and reported illuminance arriving upward toward the ceiling. These data were used to consider hourly uniformity, which was hypothesized to be relevant to the 'daylight quality' construct. Specifically, ceiling illuminance uniformity was explored as a proxy for ceiling and/or upper horizon luminance uniformity.

2.5.6 Hourly Output

The simulation output was to be stored as hourly files, by sensor, and for two conditions—Blinds Open and Blinds Closed. The blinds operation schedule was derived from the sun penetration data, described in Section 3.3.2. This schedule was used to pick between the two conditions—Blinds Open and Blinds Closed—to create a third file, with Blinds Operated values. All of this detail was preserved for subsequent analysis.

2.5.7 Simulation Challenges

Translating from one program to another for the creation of the 3D models (Ecotect to Daysim to Radiance) involved inevitable challenges, such as rectifying the orientation grids, unifying naming conventions and data formats, and assuring that rounding errors did not cause additional errors. While Daysim had previously been validated for accuracy under laboratory conditions and used extensively for preliminary design studies both by students and practitioners, it had never been used on this scale—for example to model real field spaces and generate comparable results across the range of design strategies encountered.

2.5.8 Blinds Operation

The project team quickly encountered a number of limitations with Daysim, the most serious of which were the modeling assumptions for window blinds. While Daysim had the ability to operate blinds according to a solar trigger, it was limited to one schedule, such that all blinds in a given space had to operate on the same schedule. In other words, if blinds came down when the sun penetrated through an east window in the morning, they also would come down on the west and north windows simultaneously. Since 2/3 of the study spaces had windows facing in more than one direction, this was judged by the project team to be an overly pessimistic assumption about occlusion of windows by blinds. Furthermore, as a simplification Daysim assumed that only 20 percent of available skylight (diffuse component), and 0 percent of sunlight (direct component), made it through the blinds once they were operated. While this might have been a reasonable approximation for predominantly cloudy locations, it resulted in a serious under-estimation of daylight illumination levels in predominantly sunny locations. Changes were made to the program to allow for independent blind operation by two or three orientations, but the project team was not able to modify the assumptions about the relationship of direct versus diffuse transmission through blinds.

2.5.9 New Output

As part of the project specifications, Daysim was also modified to provide additional output for analysis, beyond that from the typical task illuminance sensor grid: an illuminance grid for the reflected ceiling plan, and hours of sun penetration and percent of skydome visible from an eye-level grid. The ceiling grid was hoped to provide useful data for a uniformity metric, and the output from the eye-level grid was hoped to serve as a proxy for estimating glare conditions that might be experienced by occupants who could be seated anywhere in the space.

Ultimately, achieving full functionality for the new blinds operation and output functions in Daysim was found to be beyond the resources of the project team. Considering many alternatives, the project team eventually decided to commission the writing of a new annual simulation program. This program would build on Daysim's achievements and a use similar daylight-coefficient methodology, provide the desired functionality for blinds operation and data output, and add an important new capability—the ability to model dynamic fenestration performance via a three-step calculation process using a BSDF matrix.

2.5.10 Dynamic Radiance Approach

Greg Ward, the original author of Radiance, was commissioned to produce this new software using funds provided by Southern California Edison (SCE). He subsequently continued to refine the program with additional funds from Lawrence Berkeley National Laboratory (LNBL). The reason for developing the Dynamic Radiance approach and its innovations are detailed further in separate publications for ACEEE [Saxena 2010; Heschong 2010], also included in the Appendix C.

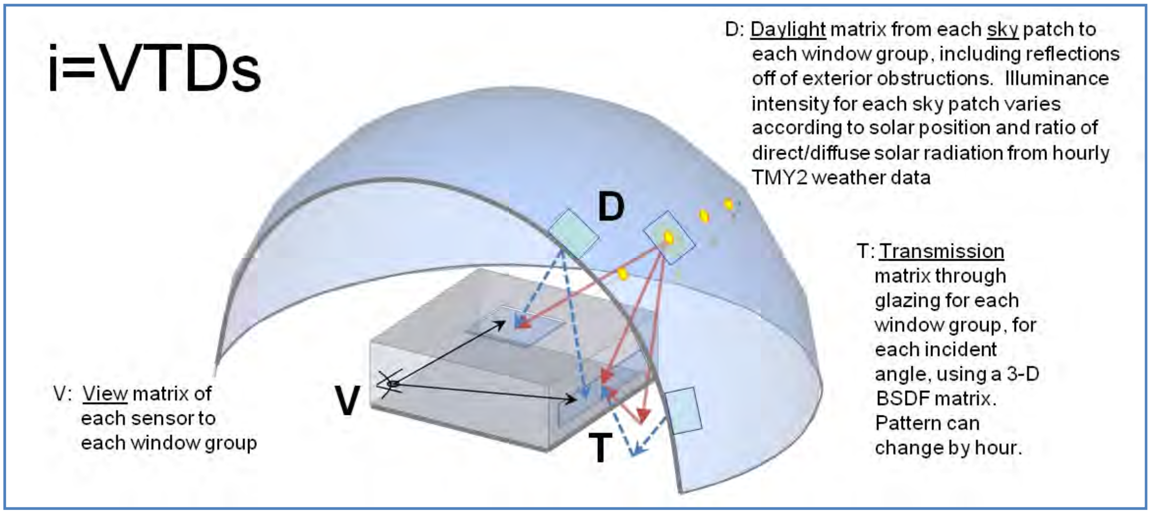
The project team spent 6 months beta-testing this new program. Output values were compared to trusted output from Daysim, and found to be nearly identical for comparable situations. Once it could competently produce the requested files for the 61 study spaces, victory was declared and the project team gave it a short-hand name: *the Dynamic Radiance approach*. It is really a suite of scripts which together produce the requested output. In this report, the term Dynamic Radiance will be used to refer to this suite of scripts. As of the writing of this report, the scripts developed for Dynamic Radiance are available on the Radiance website in a 4.0 version, but without users' instructions or a graphical users' interface. [www.radiance-online.org] The intent, as with all Radiance applications, is to manage it as an open-source code, effectively putting it in the public domain and allowing many users to continuously upgrade its interface and capabilities.

The Dynamic Radiance approach was built on the annual daylight illuminance simulation capabilities previously developed in Daysim. It has extended the two step Daylight Coefficient approach, which allows for faster simulation of annual weather conditions by reducing the number of hourly computations, into a three step approach, which inserted an additional matrix describing fenestration light transmission properties into the calculation of room illuminance. This matrix consists of a three-dimension description of how light moves through the windows or skylights, as effected by blinds or special optics. It is called a 'bi-direction scatter distribution function', or BSDF, described further below.

The three step process used by Dynamic Radiance is described by the equation: ***i = VTDs***, with the variables described below. It is also illustrated below in Figure 8.

- where i = resultant illuminance vector,
- V = a "view matrix" that defines the relation between measurements and exiting window directions;
- T = the transmission portion of the BSDF;
- Ds = the "daylight matrix" that defines the relation between incoming window directions and sky patches, varied by s = skypatch intensity

Figure 8: Dynamic Radiance Diagram



2.5.11 BSDF Matrix

The use of a BSDF matrix as an intermediary between the exterior and interior illuminance conditions of the simulation model allows the visible light transmission (VLT) and patterns of 3D light distribution through the windows to be varied by hour, according to any schedule or trigger than can be calculated by the program or provided by the user. This three step calculation process gives Dynamic Radiance the capability to model angularly dependent, complex glazings and dynamic fenestration, which includes systems as simple as manually operated Venetian Blinds to highly sophisticated optically tracking skylights. This is a major step forward in our capability to model sophisticated daylighting systems.

Currently BSDF files can be created in WINDOW-6 for one condition at a time. Thus, a given Venetian blind profile can be modeled for a 45 degree tilt. To create a dynamic BSDF matrix, a full range of tilt angles from 0 degrees to 180 degrees should be created and stored in a matrix. Dynamic Radiance would then be instructed which tilt angle to apply according to a time step or other trigger.

Eventually it is hoped that libraries of BSDF matrix files will be created via the physical testing of products, on equipment such as currently exists at Lawrence Berkeley National Labs. Other labs, at MIT and in Europe, are developing digital photography-based test equipment which promises to greatly expedite the creation of BSDF files for a variety of fenestration product scales, from micro to macro. When there is a clear pathway from product design optimization, to standard reporting formats, to simulation tools that can accept that data and compare annual performance outcomes, then the industry will have programs with the ability to distinguish those products which provide the best daylighting performance. See also discussion in Next Steps, Section 5.2.3

This project did not fully use this new dynamic capability. Rather, two static BSDF files were defined for the two conditions which had previously been modeled in Daysim—slatted blinds and translucent roller shades—such that they distributed light into the study spaces via a simple Lambertian distribution, regardless of solar angle or blind tilt. Subsequent tests, run for the Office Daylight Retrofit project [Saxena 2011] showed this to be a conservative assumption, whereby lower levels of illumination were observed in the back of the room using the Lambertian distribution than a slatted blinds setting at 45 degrees or 60 degrees, set to block all direct sunlight. See discussion under Section 3 for a further discussion of blinds modeling assumptions.

2.5.12 Window Groups

The BSDF matrix is applied to each "window group" within a space. At a minimum, a separate group is needed for each window orientation, since the surface normal is used to describe the BSDF directions. A window group can be any collection of apertures that have similar sun exposure and thus matched blinds operation, because they share the same orientation, tilt, glazing material, and/or shading configuration. For example, in the *Radiance* models, separate window groups were created for view windows with blinds versus the clerestory windows above them without blinds. Because light is additive, the Dynamic Radiance approach creates an illuminance run for each window group, with and without blinds, and then assembles the appropriate runs from each window group for each hour, based on the blinds operation schedule determined from the sun penetration analysis. Thus, the more complex the glazing geometry is in a space, the more runs will need to be done. The worst case space model had a slightly curving window wall with 17 facets.

2.5.13 Run Times

While the daylight coefficient method of Dynamic Radiance greatly added to the speed of calculation, the sheer complexity of the models, the number and density of sensor grids, and the number of runs required per model, created very long runtimes. Two annual Dynamic Radiance run were performed for each blind condition for each window group for each space. The shortest run time per space was one hour for a space with only one window group. The space with the most window groups required 28 hours to run. The average run time per space was 7 hours.

These times can be greatly reduced with fewer sensor grids, less modeling detail, and simpler parameters on the simulation settings. Indeed, in using Dynamic Radiance for the Office Daylighting Retrofit Project, that project team was able to generate a full set of runs per space averaging 15 minutes per space—a huge improvement in run times! Thus, there is strong evidence that eventually these simulations will be able to be run in minutes, if not seconds with software and hardware improvements.

2.5.14 Blinds Transmission and Operation

Assumptions about how blinds are treated within daylight simulation practices have been ill defined to date. Few studies are available about how people operate blinds and fewer are available about how daylight is transmitted through blinds. Moreover, standards and codes to date have not addressed the issue whatsoever; despite an intuitive understanding that blinds are ubiquitous in work spaces, and that blind type and operation are huge factors in daylight performance. Other proposed annual daylight metrics such as Useful Daylight Illuminance (UDI) and Daylight Autonomy have not explicitly stated how blind use should be treated to generate consistent values [Reinhart 2006a; Mardajevic 2008a].

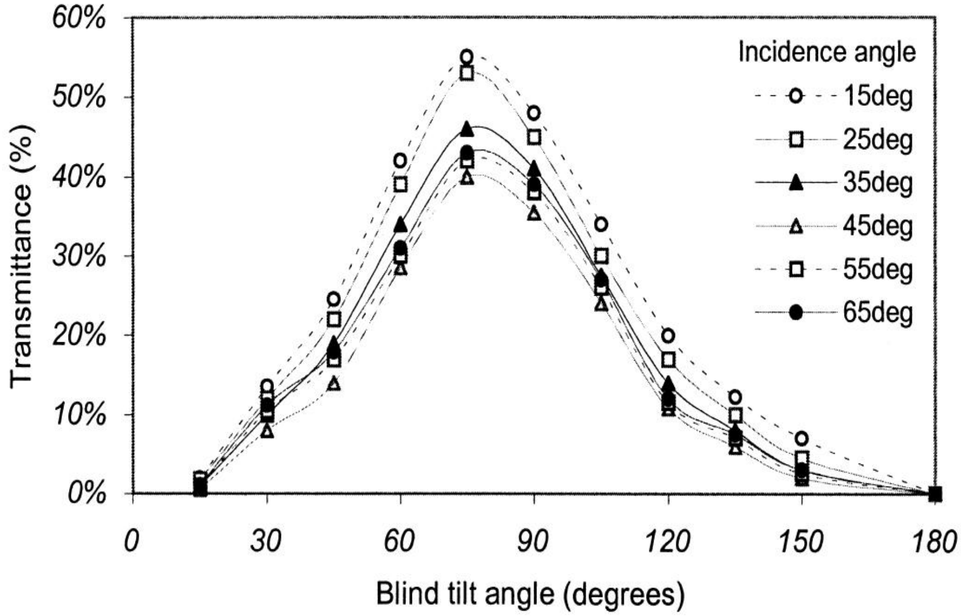
2.5.15 Research Basis

Therefore, a bold task was undertaken with this project to develop a standardized method for simulating annual blinds operation. The decisions were based upon a.) the best available research [O'Neill 2007; Reinhart 2003; Reinhart 2004a; Leslie 2005; Selkowitz personal correspondence 2008], b.) observations from site visits and survey data, and c.) also chosen to be reasonably consistent with whole-building energy simulation protocols, as described further below:

LBNL Estimates: Preliminary analysis from LBNL's Window 6 program showed that at least 10 percent of direct sunlight will be inter-reflected through an off-white flat blind positioned to block all direct beams. This value does not include addition transmission or reflections off of sills or jambs, through sting holes, or upward off of other exterior surfaces.

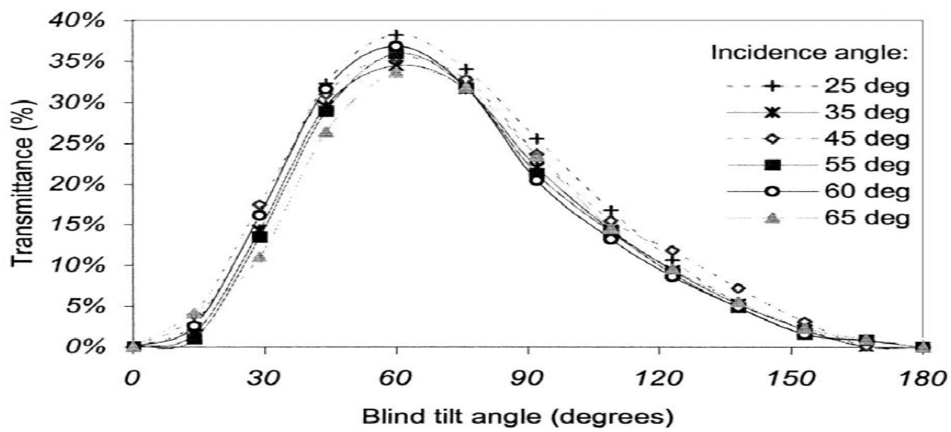
Concordia Measurements: Analysis from Concordia University showed a range of daylight transmission through blinds depending on sky condition, solar and blind position varying between 10 percent and 55 percent for the most common blinds tilt angles, with an approximate average of 30 percent. See Figure 5 and Figure 10 below, where blind tilt angles are relative to vertical plane. 60 degree blind tilt angle looks to sky, 120 degree blind tilt angle looks to ground from inside of space. Solar incidence angles are relative to horizon. [Athienitis 2002; Tzempelikos 2008].

Figure 9: Blinds Transmission, Clear Day



Source: Athienitis 2002

Figure 10: Blinds Transmission, Overcast Day

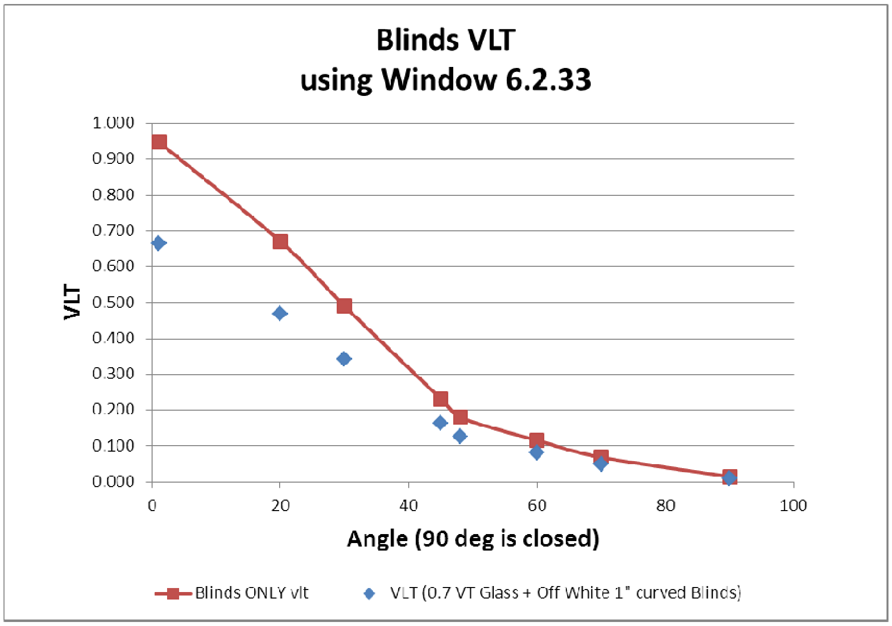


Source: Athienitis 2002

Detailed Window 6 Analysis: A separate analysis was done by HMG using Window version 6.2.33, plotted in Figure 11 below. Typical mini-blinds, with 1" off-white horizontal slats with a slight curve facing down were modeled in conjunction with 70 percent VLT glazing (blue dots on graph). The effective VLT of just the blinds was then determined mathematically (red dots and line). The analysis showed that blinds at 45 degree tilt angle had a VLT of 23.1 percent. As the blinds open to a horizontal position (0 degrees) the VLT raises rapidly to a maximum of 94.9 percent. Blinds angled to block direct sun at about 60 degrees, have a VLT of 11.6 percent.

These values are calculated by Window 6 integrating the results of 145 incoming and 145 outgoing angles. A large component of the transmission through slatted blinds is dependent upon the upward bounce of sunlight reflected off of the ground and other exterior surfaces. Thus, the net amount of daylight making it through blinds will vary greatly depending upon assumptions about the exterior environment.

Figure 11: Effective VLT of Blinds Transmission per Window 6.2.33



Survey Measurements: Site surveyors recorded blinds positions during the site surveys and crudely measured transmission through the blinds installed at each site for a variety of positions. They also interviewed site hosts on the operation of blinds in the various study spaces. None of this data was sufficient for numerical analysis, but did suggest that the study population favored fairly active management of their blinds.

Survey Self-Reports: In addition, results for the Occupant Survey, reported earlier in Section 3.3.3, show that 65 percent of the occupants reported that their blinds were fully or mostly open at the time of the survey and furthermore, 22 percent reported having some sunlight currently entering their space. Since only half of the surveys were filled out on sunny days, this number is surprisingly large. Thus, these numbers clearly suggest a preference for open blinds among the study population.

Energy Simulation Software: eQuest and Energy Plus have functions that will operate blinds according to a number of algorithms, such as irradiation on the windows, a glare calculation, or air temperature thresholds. The irradiation on the windows is commonly used in Title 24 calculations. Given that there was a strong desire to eventually integrate the daylighting analysis methodology with whole building energy analysis, it seemed wise to mimic similar operating schedules in the simulations.

2.5.15 Final Blinds Modeling Assumptions

Operation: Given the information detailed above, the blind operations assumptions used in this project are as follows:

1.) blinds are triggered by window groups; defined as groups of windows facing the same direction, in the same plane, having the same glass type and exterior shading geometry, and the same window attachment (blinds or shades)

2.) blinds are either fully deployed or completely retracted, a deployed blind completely covers the window, while a retracted blind does not cover any portion of the window

3.) two types of products were modeled, opaque blinds or mesh fabric shades

4.) blinds are triggered to deploy when 2 percent of the horizontal ‘task level’ sensors had an illuminance of 1,000 lux (roughly equivalent to 12 Watt/m2 of solar radiation) or greater, when considering <u>only</u> direct sunlight (for example no bounces) as an illumination source from any given window group

5.) blinds were reopened when the condition had passed, based on checking in one hour increments.

The ‘task level’ sensors that could see the disc of the sun was selected as a proxy for glare from low angle sun and reflections of sun patches. (For a further discussion of the selection of the task illuminance grid, see Section 4.2.2.) The result is a method that accounts for dynamic operation of a moderately active blind operator, and is similar to the logic commonly used in whole-building energy analysis programs, such as eQuest, that operate the blinds according to a solar trigger, determined by average radiation intensity on a window surface.

In the future, when comparing daylighting performance outputs between illuminance and energy simulation programs, the analyst should be careful to verify that the blinds operating triggers, and resulting schedules, are as similar as possible.

Transmission: While the operation of the blinds was dynamic and carefully nuanced by orientation, potential changes in the louver tilt angles relative to sun position were not accounted for, for example the photometrics were static. It was assumed that the blinds or shades produced a simple Lambertian (diffused) distribution of daylight with a constant transmission whenever deployed. Blinds (horizontal or vertical) were assumed to transmit 20 percent of direct sunlight and 20 percent of diffuse skylight when deployed; mesh fabric shades were assumed to transmit 5 percent of each daylight source when deployed.

These blinds transmission and operation methods should be refined as additional research becomes available. The use of dynamic BSDF files for blinds settings is recommended for any future analysis.

CHAPTER 3:
Analysis

The analysis of the data collected from the sites and generated from the simulations progressed utilized a variety of methods, and over the course of many months. The data analysis basically followed four-step process:

1. First, the expert and occupant qualitative assessments were examined for preliminary findings, then the results were consolidated into a few variables for analysis against the simulation results.
2. Next, the simulation data required considerable preliminary review to understand its distribution and assure quality control. Visual analysis via spatial plots and percentile plots increased the project teams' understanding of the behavior of the data and suggested improvements to the simulation methodology.
3. Once confidence was achieved in the simulation output, the data was processed into a suite of preliminary metrics for testing in the "simple" regression analysis.
4. Finally, a selected group of metrics were further tested using more detailed "multi-level" regression analysis.

The results of this analysis, reported in the following Section 3: Findings, informed the discussions of the IES DMC, and lead to recommendations for action reported in Section 5: Next Steps

3.1 Expert and Occupant Assessments

The expert and occupant assessment provided a large data base for analysis. It was interesting in and of itself to understand how much the experts or occupants agreed with each other internally, or between groups. Perhaps even more interesting was how the questions were interpreted by the two groups, and how responses to various questions tended to correlated with each other.

3.1.1 Preliminary Analysis

Preliminary analysis was conducted early in the process when approximately 80 percent of the data was available. Pearson's correlations, r, were calculated to find linear relationships between occupants' responses to the set of questions, experts' responses to the set of questions, and across the two populations, where r=1.00 is a perfect linear fit, r=(-1.00) has an linear inverse relationship, and r=0.00 has NO linear relationship.

Experts tended to agree with each other (high inter-rater reliability) within a given question. This came as a surprise to some of the experts, given their historic disagreements. This result does lend confidence to the questionnaire instrument.

Occupants had greater variability in responses, which would be consistent with a more diverse, more naïve population surveyed over a larger time period.

Experts tended to be more judgmental, with Likert Scores spanning the full 9-point scale, whereas occupants tended to be more tolerant in their assessment of spaces, avoiding strongly negative responses. Looking at one question in particular "The daylight in this room is always sufficient" Expert mean responses varied from 1 to 8.5 of the 61 spaces, whereas occupant mean responses only varied from 4 to 8.5. As a result of occupants avoiding strong negative responses, occupant average responses tend to be more 0.5 to 1 point more positive then the experts', but also with a wider standard deviation.

Correlations Between Experts and Occupants

When comparing the experts' responses to the occupants for the first 55 spaces where data was available, on average a positive 25 percent correlation coefficient was found between the two groups across the 15 shared questions, but many questions did not even achieve significance. The highest correlation was 0.46, or almost 50 percent, for Question 11: "I can work happily in this room with SOME of the electric lights turned off." A 50 percent correlation is not very strong and implies that there is a great deal of variation in the responses from the study population. Given this weak level of correlation one would not expect to see very high R^2 values for the subsequent regression equations.

Figure 12 shows the correlation coefficients between the average expert and the average occupant response per space to the shared questions. Correlations that were significant are shown in bold. It is interesting to note that the questions having the strongest correlations and the highest significance had to do with daylighting (11-15), electric lighting (8-9) and view quality (5-6), implying that those questions can be asked more reliably between groups. In general, the strongest correlations were found between experts and occupants in the Classroom space type, and the weakest correlations in the Other space type, Library/Lobby.

Figure 12: Correlation Coefficients, r, between Expert and Occupant Responses

Question		r	
1		0.22	I enjoy being in this room
2		0.00	I find this room visually attractive
3		0.13	Temperature in the room is always comfortable
4		-0.10	Noise level in the room are always comfortable
5		**0.43**	**I like the view I have from the window**
6		**0.24**	**I think the view out of the window is big enough**
7		0.01	I am happy with how the blinds can be operated
8		**0.28**	**The lighting conditions are always comfortable**
9		**0.36**	**The electric light in this room is always sufficient**
10		0.21	The electric lights are never too bright
11		**0.46**	**I can work happily with SOME of the electric lights turned off**
12		**0.42**	**I can work happily with ALL of the electric lights turned off**
13		**0.32**	**The daylight in this room is always sufficient**
14		**0.44**	**The daylight in this room is never too bright**
15		**0.34**	**I am able to do my work here without any glare or reflections**
Average		0.25	

Correlations between Questions

Occupant responses between questions with highly significant and positive Pearson's correlations, those over 0.50, are as follows:

- (0.74) "I like the view I have from the window" and "I think the view out of the window is big enough"
- (0.63) "I can work happily in this room with SOME (and ALL) of the electric lights turned off"
- (0.62) "I find this room visually attractive" and "I enjoy being in this room"
- (0.61) "The lighting conditions are always comfortable" and "The electric light in this room is always sufficient"
- (0.54) "The daylight in this room is never too bright" and "I can work here without any problems from glare or troubling reflections"

- (0.52) "I am happy with how the binds or curtains operate" and "I like the view I have from the window" or "I think the view out of the window is big enough"

There were NO correlations between the following:

- "The noise level in this room is always comfortable" and
    - "I find this room visually attractive", or
    - "I am happy with how the binds or curtains operate", or
    - "I like the view I have from the window" or
    - "I think the view out of the window is big enough"

This lack of correlation is actually rather reassuring, since logically one would not expect noise levels to predict those other responses. The noise question was specifically included in the survey questionnaire as a type of "placebo" question, which could provide insight into general patterns of response.

Other findings of interest are:

- Two survey questions" I enjoy being in this room" and "I find this room visually attractive" were highly correlated, especially for the experts.
- "I like the view from the window" was highly correlated with both "I find the view out of the window is big enough" and "I am happy with how the blinds can be operated."
- "The lighting conditions are always comfortable" was most strongly correlated with "The electric lighting is this room is always sufficient."

3.1.2 Grouping into Explanatory Variables

Pearson's correlations discussed above were used primarily to look for strong associations between questions in preparation for defining the explanatory variables.

The expert and occupants responses were also studied via Principal Components analysis to understand patterns of association between the multiple questions. The analysis showed that the responses to some questions consistently grouped together with either positive or negative responses, but that the pattern of grouping between experts and occupants was not consistent. The Principal Components analysis findings are shown separately for experts and occupants in Appendix B.

to aid interpretation, the grouping of questions was simplified into pairs that commonly grouped together and that represented a unified concept. Each was given a letter and descriptor, as follows:

A.) Aesthetics: "I enjoy being in this room" and "I find the room visually attractive".

B.) View: "I like the view I have from the widow" and "I think the view out of the window(s) is big enough".

C.) Occupant control: “I am happy with how the blinds (or curtains) operate”.

D.) Daylight Sufficiency: “I can work happily in this room with ALL of the electric lights turned off (using only daylight)” and “The daylight in this room is always sufficient”.

E.) Comfort: “The temperature in this room is always comfortable” and “The daylight in this room is never too bright”.

F.) Glare: “I am able to do my work here without any problems form glare or troubling reflections” and “The daylight in this room is never too bright”.

In addition to these thematic groupings, the data could still be analyzed by individual questions per occupant or expert. In the subsequent regression analysis, both approaches were used, testing equations with both the grouped questions, or with the equivalent component questions allowed to operate independently. The thematically grouped questions resulted in at least equivalent, and frequently higher, R^2 values than individual questions, suggesting confidence is warranted for the thematic groupings.

3.2 Simulation Results, Formatting and Review

This section describes the process of quality control and initial explorations with the output of the simulations. Given the complexity of the models and the simulation methodology, this was an absolutely critical and time consuming task for this project. It is only described briefly here.

A very important lesson learned was the need for an intuitive understanding of daylighting performance and visualization tools to facilitate sanity tests on the output of the simulations. Even though this process is highly quantitative, and ultimately led to regression analysis, the geometrical complexities of daylight moving through three dimensional architectural space does not lend itself to simple mathematical checks such as might be used with other datasets.

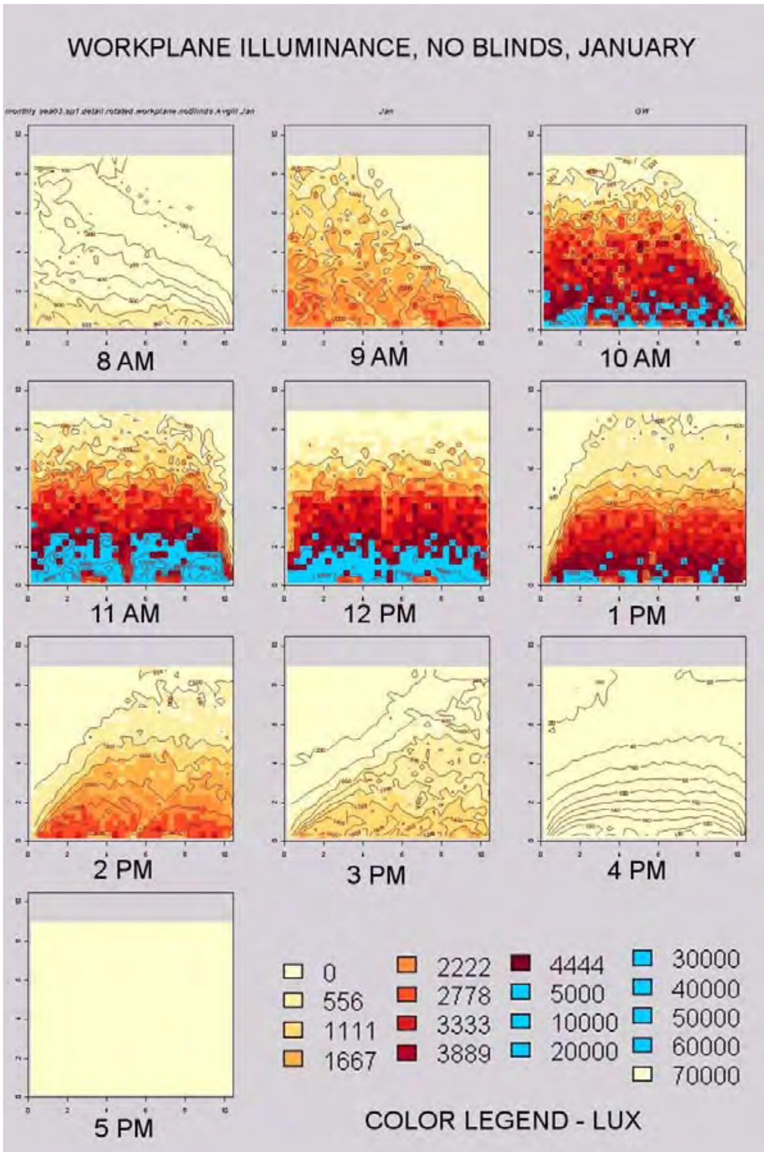
The percentile plots, discussed below in Section 3.2.2, were found to be a very useful way to compress the data into a 2D visualization tool. A version of these percentile plots may be useful as a “dashboard” tool for designers as they compare design options in that very large areas can be simplified into a few characteristic lines.

3.2.1 Quality Control via Visualization

Simply making sense of all the output data from the simulations proved a daunting task. On average, there were 9 million data points available for each of the 61 simulated spaces. The project team found it essential to be able to visualize the output geometrically, to conduct sanity checks on the data and locate potential errors.

A series of annual, monthly and hourly spatial plots (on quasi-floor plans) of the illumination output with Blinds Open, Blinds Operated and Blinds Closed were made to verify that the patterns of illumination and sunlight were logical and consistent. While the plotting was automated, the inspection was manual. This rather laborious process uncovered numerous potential modeling and programming errors that were investigated in more detail, and corrected whenever confirmed.

Figure 13: Visualization for Hourly Illuminance Values, January Averages, Blinds Open



The color contour plots in Figure 13 represent average task level monthly illuminance values for each sensor for January for a space with a single large window facing south (south is downwards) where the blinds are always open. Similar plots were created for each space with Blinds Closed, and for the month of July. These were used to verify expected behavior of sun patterns and light distribution in the space.

Figure 14: Example of Blinds Operation Visualization Tools

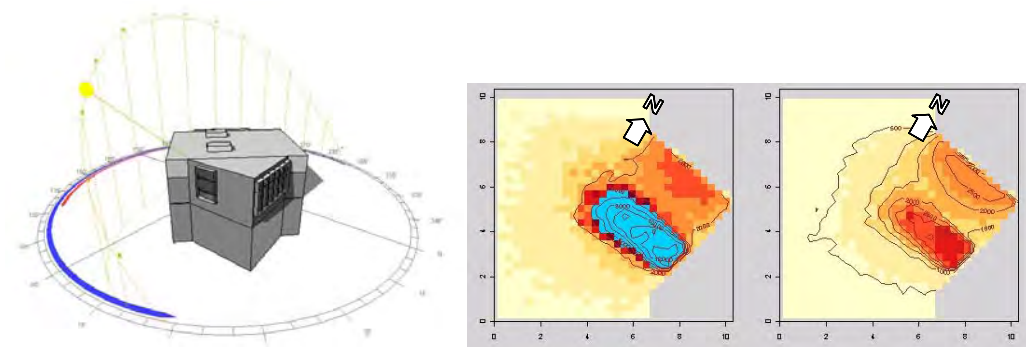


Figure 14 shows a pair of illuminance plots used to verify blinds operation after the final Blinds Operated illuminance data had been assembled, along with the 3D model of the space to the right. The illuminance plots are for 8 am on a clear January morning. The space has two windows groups, one facing north and another facing east.

The illuminance plot without blinds (left) shows that at 8:00 AM, the east-facing window is receiving direct sun (shown by blue >5000 lux), while the north-facing window receives only diffuse or reflected light. The illuminance plot with blinds operated (right) shows that, illuminance next to the east window reduces to show that blinds have been deployed, while that next to the north-facing window remains more or less unchanged. This result is in-line with what can be expected with two window groups, with blinds operating independently, where only the blinds on the east-facing window are getting deployed, while blinds on the north-facing window remain open.

Error Detection

Detected errors in modeling included “light leaks” through warped corners, incorrect surface properties, incorrect grouping of the windows into blinds groups, and incorrect specification of light transmission through interior glazing. These errors were corrected by re-specifying the models and then re-executing the scripts. Errors detected from the programing were more serious, and required new programing language. These errors included ray tracing parameters, weather references, and plotting errors.

Given the geometrical and dynamic complexities of daylight in spaces, it seems that quality control of simulation data still requires a good intuitive sense of how daylight performs in spaces, a sensibility that is best developed from the study of real spaces, or at the very least, physical scale models. Thus, it is strongly recommend that college programs include field studies with full-scale monitoring and physical scale modeling to help future professionals develop this intuitive understanding of how daylighting can be expected to vary in time and space. Without this grounding in physical experience, computer modelers will be less likely to detect problems with their simulation models and its output.

By the end of the project, substantial improvements had been made to the Dynamic Radiance Approach and the project team had high confidence that the model specifications of the 61 spaces were at least 95 percent correct. It should be noted that based on previous validation studies of Radiance, it is generally accepted that a 10 percent error in illuminance values is to be expected on top of any model specification errors [Mardaljevic 1997; Reinhart 2006b].

3.2.2 Percentile Plots of Inverse Daylight Autonomy

In addition to geometric plots described above, a variety of mathematical means were also used to examine and compare the data. One of the most useful methods compressed the data further for a snapshot of annual performance, as graphs of the percentile of illuminance levels achieved over the course of a year.

The original analysis preserved all illuminance intensity values for each hour for each sensor. Thus, for a 1000 sf space, there would be (365 days * 10 hours * 1000 sensors) = 3,650,000 unique values, potentially ranging from 0 lux to 10,000 lux. This methodology produced three full sets of this illumination data for each space: Blinds Closed, Blinds Operated, and Blinds Open.

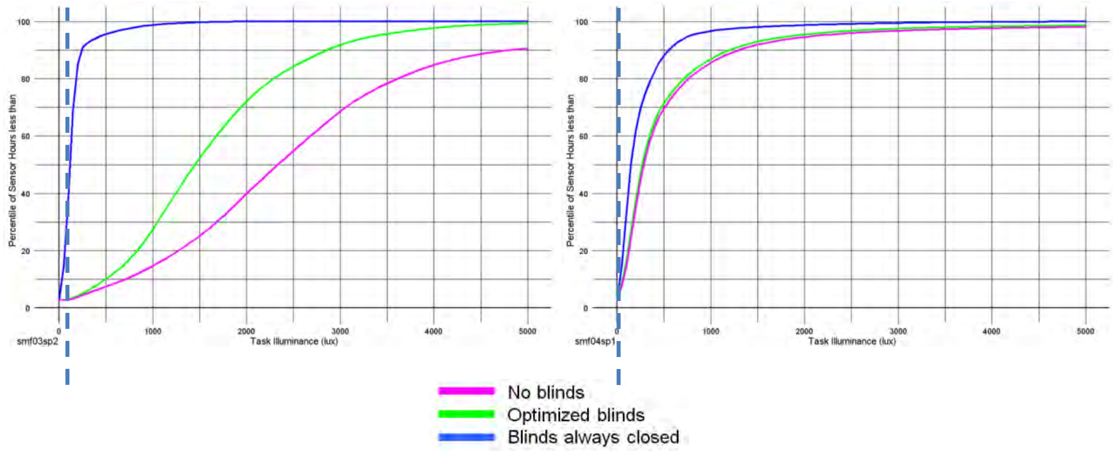
Data from all sensors and hours of each annual simulation run were plotted on a percentile curve that represents the cumulative percentage of all sensor readings that occur over a year below a given task-level illuminance shown on the x-axis. This approach followed standard statistical reporting that looks at the percentile of scores as they accumulate towards the maximum possible 100th percentile, similar to academic test reporting, where a student's SAT score of 750 might represent the 90th percentile of the larger population. These plots were named iDAp plots, for inverse Daylight Autonomy percentile plots.

The iDAp plots compressed the exceedingly complex information in the spatial plots shown in Figure 14 and Figure 15 into simple curves representative of a whole years' worth of data. The three blinds conditions were plotted separately, showing that the relationship of the three lines told a distinctive story about each space. Very quickly it was easy to recognize signature patterns for different space types.

All of the curves have a similar 'S' shape, based on the natural annual fluctuation of daylight availability over the course of the seasons, but varying in magnitude and slope. Dim spaces have curves that rise quickly and reach 100 percent at low illumination levels. Bright spaces have more gradual curves that do not reach 100 percent until further to the right, at high illumination levels.

A further exploration was begun to see if a set of points, or a single point, on these lines could usefully describe the variance observed across the 61 spaces. Appendix D.2 includes one plot for each of the 61 study spaces (using preliminary data, before a few modeling corrections were made). Below, Figure 16 illustrates plots for two spaces with very different daylighting performance.

Figure 15: Inverse Daylight Autonomy Percentile Plots



In Figure 15, illuminance intensity is on the horizontal axis from 0 to 5000 lux, and cumulative percentile of occurrences for all sensor*hours is on the vertical axis, from 0 to 100 percent. The blue (top) line shows the illuminance values for Blinds Closed, the green (middle) line for Blinds Operated, and the magenta (lower) line for Blinds Open.

The Inverse Daylight Autonomy percentile (iDAp) plot on the left is for a aggressively daylit classroom with much south facing glass. The large difference between the magenta and the green line indicates the dependence of the design upon blinds to control for sun penetration. The dotted line at the 300 lux level shows that with blinds all closed, the classroom on the left is below 300 lux 93 percent for of its sensor*hours, while less than 10 percent of the sensor*hours fall below 300 lux when blinds are operated. The large difference between the green and blue lines indicates the degree to which the optimum daylighting in the space can be defeated by keeping the blinds always closed.

In contrast, the iDAp plot on the right is for an office space with well shaded south facing windows and a light shelf redirecting sunlight form the upper windows. The very narrow separation between the magenta and green lines indicates how well shaded the windows are, while the considerably smaller difference between the green and blue lines indicates that the upper windows will continue to deliver daylight even if the blinds are always closed.

Figure 16: iDAp Plots for Two Classrooms

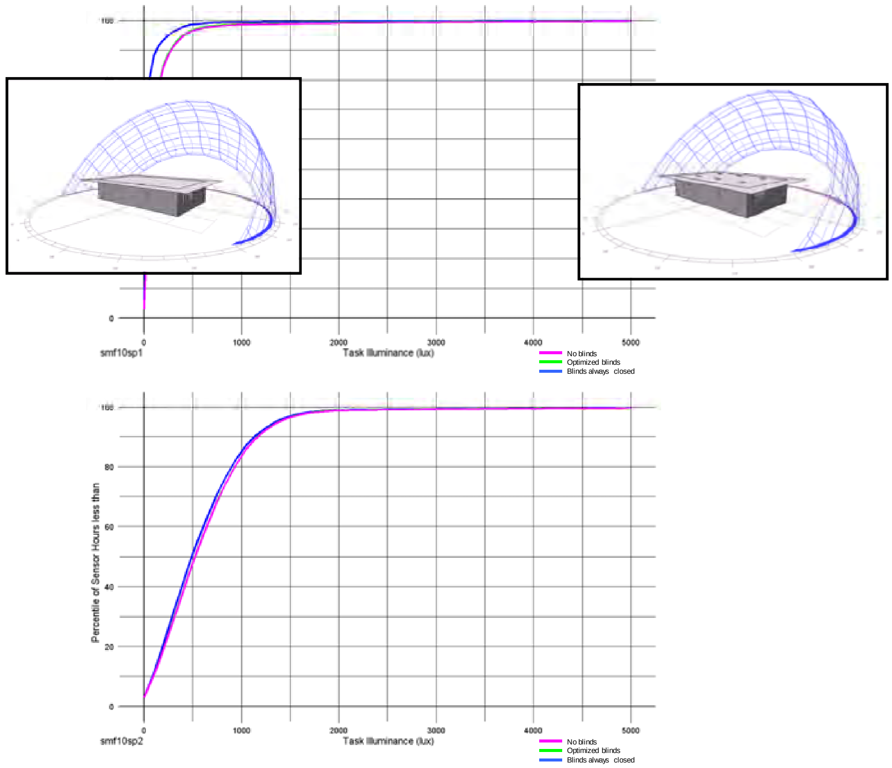
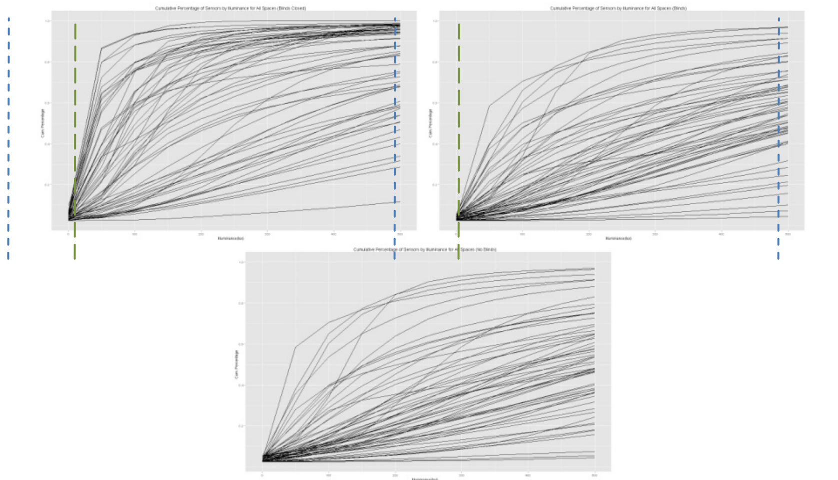


Figure 16 illustrates a similar set of plots for two classrooms, which are identical in all respects, except the one on the right was retrofitted with six tubular daylighting devices. The increase in overall daylight illumination is clearly shown by the curves shifting to the right.

Sensitivity Analysis: Visual analysis of the iDAp plots helped the project team to understand the range of illuminance patterns found in the study sample, and the sensitivity of selecting one or more illuminance thresholds to describe the daylight performance of a space. In particular, the change in patterns between the Blinds Closed and Blinds Open cases was particularly informative. It was noticed that the greatest changes often occurred at the lower illuminance thresholds, from 100 to 500 lux, and so they were examined in greater detail.

Figure 17 provides much reduced images of some of these comparison iDAp plots, allowing the viewer to see the overall pattern, from right to left, for Blinds Closed, Blinds Operated, and Blinds Open, form 0 lux to 500 lux. Dotted lines are drawn for reference, blue short dashes at 200 lux and green longer dashes at 300 lux. It can be observed that among the three cases the diversity of patterns can best be described by some point in the middle range, for example around 200 or 300 lux. Clearly, the darker the space, as in Blinds Closed, the more important the lower value becomes. This analysis also contributed to the later recommendation of 300 lux as a useful threshold to differentiate the performance of spaces.

Figure 17: iDAp Plots at Low Illuminance for all 61 Spaces



Naming conventions: After working with the data for a number of months, the project team concluded that regular Daylight Autonomy which reported on the percentage of time above a given illuminance threshold (as opposed to inverse, the cumulative time below a threshold) was easier to explain and more intuitive for people to understand. The IES Metrics Committee agreed, and thus, midway through the project reporting switched to standard Daylight Autonomy. However iDA remained the values in the dataset and regression analysis, usually labeled DAqXXX. The conversion between the two is easy, since: *DA = 1-iDA*.

3.3 Selection of Independent Variables

The data used to generate the iDAp plots were also used to generate a variety of candidate metrics that could be tested via linear regression equations against the expert and occupant assessments. Each metric reduces the raw annual simulation data into a single value per space.

The metrics were created from three sources: to imitate existing metrics as closely as possible, some were nominated by the IES DMC, or represented a range of conditions that the project team wanted to test. The metrics fell into two basic topic groups: those attempting to describe 'daylight sufficiency" and those attempting to describe some aspect of visual quality, such as glare, contrast or uniformity. First they were tested using the simple regressions, and then a selected group studied more thoroughly using the multi-level regressions described in Section 4.4.

3.3.1 Daylight Sufficiency

Daylight sufficiency was conceptualized as a metric that could best predict occupant satisfaction with the daylight illumination levels over time. A wide variety of metrics were tested in this group.

The largest group were the sensor*hours percentile values at a range of illuminance thresholds of interest: 200, 300, 400, 500, 750, 1000, 1500, 2000, 3000, and 5000 lux. Each one of these values was essentially a 'slice' through the iDAp plots at different illuminance levels. These variables were labeled DAqXXX to indicate inverse Daylight Autonomy percentiles at various illuminance quantities 'q'. At the upper levels, they also could be considered candidates for an "illuminance excessiveness" metric, previously defined as DAmax.

For example, a metric called 'inverse Daylight Autonomy 300 lux' (DAq300) was calculated by first selecting only the Blinds Operated task illuminance data between 8:30 and 17:30, corrected for daylight saving time. Then all of the resulting values were ordered for all sensors, and all included hours, according to illuminance value. The DAq300 value was then the percentage of sensor-hours where the illuminance was below 300 lux. (Again, a simple conversion of 1-DAq300 = percentile of values above 300 lux.)

In addition to the inverse Daylight Autonomy percentile values, independent variables were also constructed from the continuous illuminance data to represent a range of alternative annual daylight metrics that had already been proposed by various researchers [Mardaljevic 2000; Walkenhorst 2002; Reinhart 2006a]. They can be considered in two groups: annual, for example those that utilize a years' worth of weather data, and single-point-in-time, for example those that are calculated for one hour at a specified condition:

Annual:

- **UDIa**, Useful Daylight Illuminance achieved, percentile of sensor*hours between 100 lux and 2500 lux, with Blinds Open
- **DSP**, Daylight Saturation Percentage (percentile of sensor*hours greater than 400 lux, less twice the value greater than 4000 lux), Blinds Operated
- **cDA**, Continuous Daylight Autonomy (percentile at 500 lux, plus proportionate percentile for all time less than 500 lux), Blinds Operated

Single Point in Time:

- **DF**, Daylight Factor, percent of space above 2 percent Daylight Factor under fully overcast skies, found by selecting hour with highest diffuse component and then the lowest direct component
- **LEED 10** am: defined as the percentage of sensors at or exceeding 25 foot-candles at 9 am clock time on the clearest day within 10 days of Sept 21st in the weather file, Blinds Operated
- **LEED 3** pm: similar to above for 3 pm clock time, actually at 4 PM for daylight savings time that applies in September

3.3.2 Visual Comfort Proxies

The IES Metrics committee had agreed early on that "daylight sufficiency metrics were not sufficient" and must be considered along with other metrics that would predict visual comfort within the space. This quest was complicated by the other limitations of the simulation approach, which made it impossible to consider any of the existing glare metrics that required luminance data and analysis from a fixed point of view. Thus, the project team and DMC discussed a number of other approaches to metrics that could be derived from the simulations and that might predict visual comfort. These can be grouped into five types, each discussed further below: excessive daylight illuminance, sun penetration, sky view factors, uniformity, and building characteristics.

3.3.3 Excessive Daylight

A number of researchers and practitioners had hypothesized that high illuminance levels could be used to predict visual discomfort. Mardaljevic suggested using >2500 lux as the upper threshold. The CHPS committee decided in crafting DSP that any amount greater than ten times the target illuminance as a upper threshold. Thus, if 400 lux was the goal for classrooms, then 4000 lux should be set as an upper limit. LEED had recommended using 300 fc (3000 lux). Others have suggested that 5000 lux is a clear indication of the presence of direct sunlight, and so could be used as a proxy for the presence of sunlight in a space. Following this thinking, the project team tested Daylight Autonomy percentiles from 1000 lux to 5000 lux as potential proxies for glare or visual discomfort from excessive daylight illumination. These were all defined as illuminance at the task level.

- **DAqXXX**, for values from 1000, 2000, 3000 and 5000 lux, with Binds Closed, Blinds Operated, and Blinds Open (12 conditions)

3.3.4 Sun Penetration

There was also the ability, given the simulation methodology used in Dynamic Radiance, to isolate the "direct sun" component of the annual calculation, and report on the number of hours and/or intensity of direct sunlight at each sensor. The project team had specially created the eye-level grid of sensors at four feet above the floor as a proxy for occupants' eyes in a seated position. Dynamic Radiance had already been run to predict only the sunlight (zero bounces, no sky contribution) intensity at the eye-level grid with Blinds Open to determine the operating schedule for the blinds. (If more than 2 percent of the sensors were determined to be in sunlight for any window group, the blinds were scheduled to be closed for that hour.) This data preserved solar illuminance intensity by hour by sensor. Following the protocol recommended by Christoph Reinhart in Daysim, the definition of "sunlight" was originally direct sun illuminance above 4000 lux.

Initial studies, all for 4000 lux at eye-level sensors, Blinds Open, direct sun only:

- ***nHours***, number of hours blinds are required to be closed, using the 2 percent sensor trigger (and logarithmic version)

- ***SenHours*,** number of sensor hours that exceed 4000 lux, divided by number of sensors

In later analysis, discussed in Section 4.2.2, the project team subsequently reconsidered both use of the eye level sensor grid and the 4000 lux threshold. For these later studies, which considered for both 1000 lux and 4000 lux, at both eye-level and task level sensors, Blinds Open, direct sun only, a larger group of metrics were tested:

- ***nHours***, number of hours blinds are required to be closed, using the 2 percent sensor trigger
- ***SenHours*,** number of sensor hours that exceed threshold, divided by number of sensors
- ***MaxHours*,** number of hours exceeding threshold, for the one sensor seeing the most hours
- ***q90Hours***, number of hours exceeding threshold, for the 90th percentile sensor
- ***MaxArea***, maximum area in a single hour exceeding threshold
- ***q90Area***, 90th percentile of area in a single hour exceeding threshold, divided by the number of sensors
- ***sunUnif***, Max Area divided by SenHours (ratio of maximum area to average area)

3.3.5 Sky View Factors

Some of the IES DMC hypothesized that the amount of sky visible from a space might correlate with glare problems or visual discomfort. The Dynamic Radiance approach included the capability for sensors to report the proportion of sky that each could see, using the methodology of defining 2305 sky patches (See the SimBuild paper, in Appendix C.6, for further detail on sky patch methodology). First the skydome hemisphere was divided into three bands: low, medium and high. Low included all parts of the sky from 0 to 30 degrees above the horizon; medium from 30 to 60 degrees; and high from 60 degrees to the zenith at 90 degrees. Then two basic definitions of skyview were created, either the average percent of a given band of the skydome visible to all sensors in the space, or the single largest percent of a segment skydome visible to any sensor. Combinations of two or three segments were also tested.

- **Low**, percentage of sensors in space that can see greater than 0.1 percent of sky in 0-30 degree band
- **Med,** percentage of sensors in space that can see greater than 0.1 percent of sky in 31-60 degree band
- **High,** percentage of sensors in space that can see greater than 0.1 percent of sky in 61-90 degree band
- **Total**, percentage of sensors in space that can see greater than 0.1 percent of sky in full hemisphere
- **LowMean**, mean percent of sky in 0-30 band seen by sensors in space

- **MedMean**, mean percent of sky in 31-60 band seen by sensors in space
- **HighMean**, mean percent of sky in 61-90 band seen by sensors in space
- **TotalMean**, mean percent of total hemisphere seen by sensors in space
- **LowMedMean**, mean percent of sky in 0-60 band seen by sensors in space
- An exponential version of LowMedMean was also tried.

3.3.6 Uniformity

Uniformity metrics are common in the specification of electric lighting, but vary in format and criteria with different application types. Min/max and min/average illuminance ratios are common for indoor and outdoor lighting respectively, along with a few applications using more sophisticated mathematical concepts such as standard deviation or coefficient of variance.

However, both indoor and outdoor electric lighting systems tend to operate under a much smaller range of illuminance conditions than do daylit spaces. Indoor lighting might range from 1 to 1000 lux, and outdoor lighting from 0.01 to 10 lux, whereas a daylit space might easily range from 1 to 10,000 lux, for example at least additional order of magnitude.

Another common difference between illuminance uniformity in daylit versus electrically lit spaces is the dimensions over which uniformity is judged. For a daylit space that dimension may be the full width of the room or building, while the gradients for the electric lighting system are most likely to follow a standardized grid of space of luminaires, such as 10 feet on center.

Furthermore, electric lighting is commonly judged by horizontal illuminance, since the fixtures are usually mounted in the ceiling, whereas daylighting, especially from windows, may contribute more importantly to the illuminance of vertical surfaces. Given all these differences, a number of daylighting practitioners have expressed concern that standard IES recommendations for uniformity of illuminance are not appropriate for daylit spaces.

In discussions with the IES DMC and the project team, it was felt that a measure of luminance uniformity along the upper walls of a space would be ideal. Given the limitations of the simulations, it was felt that illuminance uniformity on the ceiling surface might serve as a reasonable proxy for the visual horizon of the upper wall surfaces. Thus, the project team took the step of specifying the third illuminance grid of ceiling sensors looking down. The illuminance levels that they would report would be a function of many inter-reflections within the room, and were likely to correlate well with the illuminance levels of the upper walls. Thus, illuminance data from the ceiling grid was considered as the prime candidate for uniformity analysis. The ceiling grid files were generated for the three blinds conditions, and then analyzed for the Blinds Operated case.

The following uniformity metrics, examining illuminance data form the ceiling grid for the Blinds Operated case were initially considered:

- **CV**, coefficient of variation (standard deviation/norm) of ceiling plan illumination
- **IQR**, hourly interquartile range (25-75) of ceiling plane illumination
- **IDR**, interdecile range (10-90) of ceiling plane illumination
- MM,
- MaxtenNinty
- Plus, 90th percentiles and Medians of above

3.3.7 Building Characteristics:

Basic descriptions of the spaces were also included in the regressions on the theory that they might be equally as valid in predicting occupant responses as the metrics developed from the simulation data, or that they might be important qualifiers of simulation output. Many other space characteristics are used by current prescriptive code definitions, such as window-to-wall ratio, window head height, or affective aperture. These additional metrics could have been derived from the site data, but were not tested. Those tested are shown in the bulleted list below.

- ***Blinds type***, roller shade, slated, or none
- ***Space type***, Classroom, Office, or Library/Lobby
- ***Location***, Seattle, New York, California coastal, California inland
- Skylights, yes/no
- LightShelves, yes/no
- Number of window orientations, 1-4
- ***Orientation 1***, any space with windows within 30 degrees of south
- ***Orientation 2***, any space with windows oriented with 60 degrees of east or west, but no south facing windows
- ***Orientation 3***, any space with none of the above, but windows facing north or toplit

In general, the study sample was created to support statistical analysis by space type, with proximately equal numbers in each group. The other space characteristics were 'as-found' and thus were not as well supported in the distribution of the study sample.

3.4 Regression Analysis

Linear regression was the basic tool used to compare the simulation output, derived from the site surveys, to the occupant and expert assessments, derived from the questionnaires. The simulation data and the questionnaire results were assembled into a master database, and then processed both into the list of potential independent and dependent variables described above. This made a summary dataset with one row for each space, which then could be pulled into a series of regression equations.

The discussion below first describes the process of using the simple regressions to filter the long list of potential explanatory variables to those with the greatest promise, and then the more complex testing of the multi-level or "nested" regressions that allowed more precise fit and provided insight into the components of each equation. The two terms are used interchangeably in this report. Given the long list of variables considered, only samples of those that were found most interesting are presented and discussed here.

3.4.1 Simple Regressions

The candidate metrics were then set as the dependent variable in a simple linear regression, with the questionnaire items and space characteristics, (both singly and in groups) as the independent variables. The metrics with the strongest relationship to the qualitative assessments were chosen for further study using the nested regression method described below

.

Figure 18: Sample of Simple Regressions, Large

Metric	Blinds	Intercept	A	Ap	B	Bp	C	Cp	D	Dp	C21	C21p	C22	C22p	R2	AdjR2	n
q200	Operated	0.554	-0.005	0.327	-0.004	0.334	0.005	0.149	-0.023	0.000	-0.004	0.245	-0.014	0.000	0.153987	0.1462	655
q300	Operated	0.687	-0.006	0.287	-0.005	0.258	0.007	0.098	-0.026	0.000	-0.005	0.201	-0.017	0.000	0.167112	0.1594	655
q2000	Operated	1.041	-0.008	0.004	-0.002	0.376	0.004	0.024	-0.009	0.000	-0.004	0.062	-0.006	0.005	0.14442	0.1365	655
q3000	Operated	1.019	-0.005	0.000	-0.001	0.236	0.002	0.014	-0.004	0.000	-0.001	0.233	-0.001	0.143	0.109281	0.1010	655
q5000	Operated	1.000	-0.001	0.007	-0.001	0.053	0.001	0.024	-0.001	0.012	0.000	0.968	0.000	0.701	0.051682	0.0429	655
q200	Open	0.478	-0.003	0.529	-0.009	0.022	0.006	0.109	-0.022	0.000	0.000	0.907	-0.011	0.002	0.137704	0.1297	655
q300	Open	0.614	-0.004	0.450	-0.011	0.018	0.007	0.087	-0.026	0.000	0.000	0.986	-0.014	0.001	0.151268	0.1434	655
q2000	Open	1.039	-0.006	0.126	-0.011	0.000	0.009	0.001	-0.013	0.000	-0.003	0.366	-0.007	0.016	0.124303	0.1162	655
q3000	Open	1.020	-0.004	0.106	-0.009	0.000	0.007	0.000	-0.007	0.000	0.000	0.855	-0.002	0.166	0.113731	0.1055	655
q5000	Open	0.992	-0.001	0.289	-0.005	0.000	0.003	0.000	-0.002	0.002	0.001	0.074	0.000	0.885	0.109847	0.1016	655
q200	Closed	0.838	-0.011	0.143	0.018	0.004	0.010	0.060	-0.028	0.000	-0.007	0.186	-0.021	0.000	0.122633	0.1145	655
q300	Closed	0.904	-0.013	0.063	0.019	0.001	0.009	0.076	-0.024	0.000	-0.007	0.194	-0.019	0.000	0.119259	0.1111	655
q2000	Closed	1.013	-0.004	0.003	0.004	0.001	0.000	0.708	-0.004	0.000	-0.001	0.251	-0.002	0.044	0.092593	0.0842	655
q3000	Closed	1.007	-0.002	0.010	0.001	0.191	0.000	0.390	-0.002	0.001	0.000	0.427	-0.001	0.217	0.057139	0.0484	655
q5000	Closed	1.000	0.000	0.098	0.000	0.196	0.000	0.018	0.000	0.073	0.000	0.857	0.000	0.784	0.024028	0.0150	655

shows output from the simple regressions testing a sequence of DAq200, 300, 2000, 3000, 5000 values against a large suite of explanatory variables, Questions A, B, C, D and 21 and 22. The red color highlights those equations with the highest adjusted R^2 (adjusted for the number of variables considered). The blue color highlight those variables with significant values ($p<0.10$). It is notable that in this group Question D shows a consistently significant and negative relationship to all of the tested outcomes. DAq300 is has the highest R^2 for both the Blinds Operated and the Blinds Open groups, while DAq200 has a barely higher R^2 in the Blinds Closed group. Keep in mind that the DAqXXX values are inverse Daylight Autonomy percentiles, so the negative relationship predicts that brighter spaces are strongly associated with higher ratings on Question D, the daylight sufficiency combination. Similarly brighter spaces as indicted by lower DAq200,300 and 2000 values also predict Question 22 “I have no problems with glare or troubling reflections in this space.”

Figure 19: Sample of Simple Regressions, Small

Metric	Blinds	Intercept	C21	C21p	C22	C22p	R2	AdjR2	n
q200	Optimized	0.413	-0.005	0.164	-0.015	0.000	0.042342	0.0401	844
q300	Optimized	0.527	-0.006	0.164	-0.019	0.000	0.054433	0.0522	844
q2000	Optimized	0.956	-0.002	0.396	-0.008	0.000	0.038607	0.0363	844
q3000	Optimized	0.976	-0.001	0.407	-0.002	0.033	0.014412	0.0121	844
q5000	Optimized	0.989	0.000	0.717	0.000	0.902	0.000177	-0.0022	844
q200	Open	0.331	0.000	0.998	-0.012	0.001	0.020479	0.0181	844
q300	Open	0.439	0.000	0.962	-0.017	0.000	0.030359	0.0281	844
q2000	Open	0.911	0.002	0.370	-0.012	0.000	0.025762	0.0234	844
q3000	Open	0.939	0.003	0.112	-0.005	0.002	0.011367	0.0090	844
q5000	Open	0.960	0.002	0.000	-0.001	0.167	0.017369	0.0150	844
q200	Closed	0.794	-0.019	0.000	-0.017	0.002	0.064444	0.0622	844
q300	Closed	0.869	-0.019	0.000	-0.014	0.005	0.063919	0.0617	844
q2000	Closed	0.992	-0.003	0.009	-0.002	0.036	0.034157	0.0319	844
q3000	Closed	0.993	-0.001	0.055	-0.001	0.192	0.016463	0.0141	844
q5000	Closed	0.995	0.000	0.217	0.000	0.729	0.002165	-0.0002	844

Figure 19 shows the output from a similar suite of equations, but this time only considering two explanatory variables, Questions 21 and 22. Here Question 22 "I have no problems with glare or troubling reflections in this space" has a consistently significant and negative relationship to the inverse Daylight Autonomy Values for all except DAq5000. However, in this case, the predictive relationship is considerably weaker than when all possible explanatory variables were allowed into the equation, as shown earlier in Figure 18. In this case it seems that the brighter the space is from daylighting, especially when all blinds are Closed, the fewer problems occupants have with reflections and glare. Another way to say this is the more daylight that can be expected to get into a space even when the blinds are all Closed, the fewer reported problems with reflections and glare. This would likely represent spaces with skylights, north windows with no blinds, and/or clerestories with no blinds.

It is also perhaps interesting that only in the Blinds Closed case, does the Question 21 "The daylight in this space is never too bright" have a significant relationship to the outcome, where once again, the brighter the space, the more likely occupants are to judge that the "space is never too bright". While this might seem illogical with a literal reading of the question, if instead, occupants were interpreting it to mean that they had no problems with "excessive brightness" or glare, then it is logical that the brighter spaces might have less contrast glare.

This process allowed the analysis to focus attention on fewer possibilities using the more elaborate process of creating nested regressions, as described in the following section.

3.4.2 Nested Regressions

The next step in the regression analysis was to create multilevel (nested) regressions that were structured to allow experts and occupants to have different relationships to the dependent variable being tested. These regressions were examined both for the whole data set of 61 spaces, and also separately by space type. The nested regressions gave more precision in the analysis, providing insight into how a metric performed differently in different space types and according to both the expert and occupant assessments.

These regressions were used to evaluate all of the candidate metrics that were selected from the simple regressions, based on the direction and size of the relationship of the metric to the occupant and expert survey results and the R^2 goodness of fit statistic for the regression as a whole. Priority was given to equations where the explanatory variables were significant for all three space types, and the beta values more similar, or at the very least, pointing in the same direction.

3.4.3 Space Type Equations

The sub-equations examining space types had only about 1/3 the population of the of the whole data set, and so logically would tend to have lower significance. However, the space level equations often showed tighter fit then the whole group. In general, the Library/Lobby space type had the loosest fit, while the Office and Classroom types often had better fit than the group as a whole. This can largely be explained by greater homogeneity of the classroom and office occupants, in time, space, and demographics, relative to the Library/Lobby group, where:

- Occupants had a choice of where to locate within the space, rather than a fixed task location
- Occupants spent the least amount of time in these spaces, and were more often "casual users", rather than daily occupants
- The smallest number of observations from occupants (n= 121 for Library/Lobby versus n=175 for Offices and n=288 for Classrooms)
- Another interpretation could be that illumination conditions have a smaller range of acceptability for Classroom and Office space types, with more permanent task locations and longer term occupants.
- While the differences in findings for the three space types is interesting, given that the differences were not statistically significant, it is not recommended that those differences be pursued as the basis for forming criteria among the three space types.

3.4.4 Blinds Type and Climate Locations

Multi-level regressions were also tested with either the climate location (New York, Seattle, or California) or the blinds conditions (roller shade, slatted blinds, or none) instead of the space type. This was entirely feasible with the project's multi-level regression method, and there were sufficient data points to support this level of analysis. However, testing showed there was not significance between the three options, and so this analysis approached was halted. Further investigations could be done examining such details as location type, blinds type, or other space characteristics; however, a larger data set is probably needed to support certainly from such analysis.

CHAPTER 4: Findings

The section below reports on the findings for the final multi-level regression analysis for the two major efforts of this project, those addressing daylight sufficiency and those addressing visual comfort. The interpretation of these findings relative to codes and standards or other uses is discussed in the following Section 5 on Next Steps.

4.1 Daylight Sufficiency

One of the top priorities of the IES committee was to establish a useful description of Daylight Sufficiency as one dimension of the visual quality in daylit spaces. The goal was to identify ONE metric for daylight sufficiency that could make the conversation across all user groups more coherent. By consolidating discussions about daylight sufficiency via the use of a common shared metric which enables quick comparisons across design strategies, it is hoped that adoption of a singular metric will accelerate other aspects of research and development on daylighting performance. Below is the summary recommendation from the findings discussed in this section.

Summary of Project Team Recommendations: Based on the evidence discussed below and other considerations, the project team recommends that 300 lux be used as the illuminance threshold for daylight sufficiency metrics, at the least for the three space types considered in this study. The basis for this recommendation is discussed in Section 4.1.1 below. The team also recommends that no upper illuminance threshold be used for determining the visual quality of a space, as discussed in Section 4.1.2. The team's preferred metric, given both that it is substantiated with evidence from this field study and that it promises great utility in professional practice, is the spatial Daylight Autonomy metric discussed in Section 4.1.5. The project team recommends adoption of $sDA_{300,50\%}$, based on 50 percent time at 300 lux as the structure for the metric, which is believed will be most widely applicable and easily understood by the majority of user groups[1]. The performance criteria based on this metric can then be adjusted to more stringent (greater percentage of applicable area) or forgiving (less percentage of area), depending on the application or user needs.

4.1.1 Inverse Daylight Autonomy

The analysis using iDAp values found that three candidates, DAq200, 300 and 500 all had merit in describing daylight sufficiency, as judged by Question D: "I can work happily in this room with ALL of the electric lights turned off" and "The daylight in this room is always sufficient". For these regressions, Spaces n=61, Occupants n=484, and Experts n=324. Descriptive statistics are included in Appendix B.2.

[1] And the IES DMC voted on 3/25/ 2011 to adopt this definition.

Figure 20 shows the results for the three central iDAq values under consideration. The adjusted R^2 values are colored in red, with the darkest color showing the strongest values. While the differences are fairly subtle, iDAq200 shows the strongest R^2 for the Other space type, iDAq300 is strongest for the Office space type, and DAq500 is strongest for the classroom space type. Overall, the iDAq500 has the highest overall R^2, this value is being strongly driven by the higher component value for the Classroom space types.

The two columns labeled DP and EDP in Figure 20 show the probability that the explanatory variable is significant, with those values where P>0.10 are colored in blue. All but one variable in this set are significant.

Figure 20: Multi-level Regressions for iDAq200, 300 and 500

Group	Dependent	AdjR2	D	DP	ED	EDP
All	q200	0.1870	-0.020	0.000	-0.034	0.000
Class	q200	0.1505	-0.039	0.000	-0.012	0.000
Office	q200	0.3341	-0.008	0.000	-0.047	0.000
Other	q200	0.4006	0.002	0.574	-0.057	0.000
Group	Dependent	AdjR2	D	DP	ED	EDP
All	q300	0.2020	-0.021	0.000	-0.040	0.000
Class	q300	0.1735	-0.045	0.000	-0.021	0.000
Office	q300	0.3566	-0.008	0.001	-0.052	0.000
Other	q300	0.3982	0.006	0.049	-0.060	0.000
Group	Dependent	AdjR2	D	DP	ED	EDP
All	q500	0.2303	-0.020	0.000	-0.046	0.000
Class	q500	0.2185	-0.045	0.000	-0.036	0.000
Office	q500	0.3512	-0.009	0.000	-0.051	0.000
Other	q500	0.3606	0.010	0.000	-0.056	0.000

Beta values are shown in the columns labeled D for occupants and ED for Experts, where positive values are highlighted in purple. It is noteworthy that in this set only one variable consistently has a positive beta—that for occupant assessments of the Other space type. The negative beta values predict that as the Likert score goes higher, the iDA value will go lower. Since this is *inverse* Daylight Autonomy, the brighter the space, the more people are satisfied with the sufficiency of the daylight illumination. This is true for all except the occupants of the Other space type, that show a positive relationship (purple highlight). An interpretation of this discrepancy is that the positive occupant beta serves as a corrective factor to the experts' beta, for example that the occupants of the Other space type are content with lower levels of daylight illumination than predicted by the experts.

Looking at the beta values for the equations (the column labeled "D" for occupants and "ED" for Experts) Figure 20 shows that in the Classroom space type the occupants had the strongest opinions about illuminance levels, where their beta values are 1.5 to 3 times larger than those of the experts, while in the other two space types, the experts had stronger opinions than the occupants.

Figure 21: Plots of Multi-level Regressions for iDAq200, 300 and 500

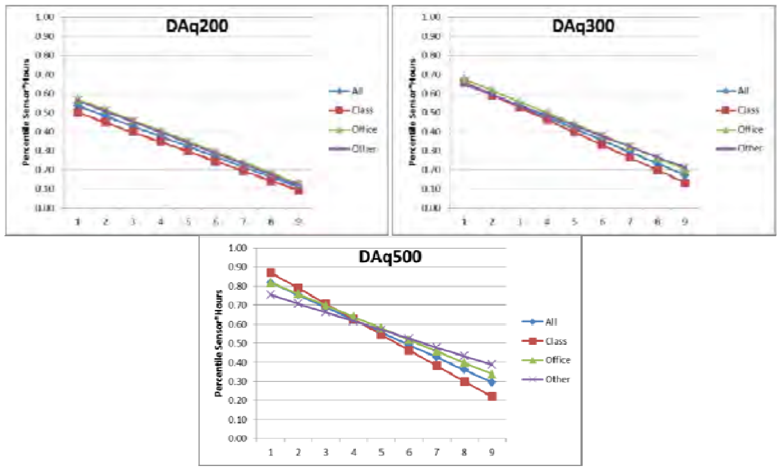


Figure 21 shows plots of the predictions of the three equations for the three levels under consideration, where the vertical scale is the percentage of sensor*hours predicted by the Likert score along the horizontal axis, combining weighted predictions of both experts and occupants. It is notable that for DAq500 the lines for the three space types start to diverge more in their slope, suggesting there is less consistency in the prediction between space types as the illumination threshold increases. This was found this to hold across all of the illuminance thresholds tested, where there was the strongest preference for brighter spaces, or dislike of darker spaces, in the Classroom space type.

The IES Committee was presented with an earlier, preliminary version, of this data and asked to vote on their preferred threshold, and also if there should be more than one threshold should be considered. The consensus of the group was to focus solely on the 300 lux threshold for further analysis for the following reasons:

- The difference between the three central choices was not large. Because daylight illumination is a natural continuum, with a gradual distribution from low to high throughout the day and seasons, any illumination threshold will also predict those thresholds nearby. Thus, the choice of the threshold is not a critical acceptance issue, but rather a professional convenience, allowing consistent comparisons and evaluations of alternative spaces.

- 300 lux had the advantage of being consistent with current IES recommendations for target illumination levels for the three space types considered

- It is more important to provide discrimination in the performance between spaces at the marginally acceptable ranges, for example lower illumination thresholds, then at the higher ranges. Thus a choice of 300 lux is preferred over 500 lux.

- The DAq500 findings for the Classroom type were potentially driving the R^2 for the All group equation, given the larger number of spaces in the sample, the larger number of occupants (49 percent of the total) and the greater consistency in the demographics of students
- Since the blinds operation model used in this project was optimistic, any simulation methodology assuming Blinds Closed more often would result in lower overall annual iDAp illumination values. Therefore, choosing the lower (300 v 500) threshold would likely be more applicable if more conservative blinds operation assumptions were used in the future.

Discussion ensued with a suggestion that for future space types, other thresholds might be considered—for example, for warehouses, a 100 lux threshold might be more appropriate—however, that consideration should wait until further research was available specific to those space types.

4.1.2 Upper Limits on Daylight Autonomy

Looking at the higher illuminance thresholds—1000 to 5000 lux—it was found that higher illuminance iDA thresholds also predicted agreement that the daylight levels were sufficient, and had positive association with the statement "The daylight in this space is never too bright". In other words, the analysis could not detect an upper threshold at which the occupants or experts started to complain that the daylight was too bright, or was negating their satisfaction with daylight sufficiency.

Figure 22: "Reverse" Regressions for Question D

Group	Dependent	AdjR2	D	DP	ED	EDP
All	q2000	0.1430	-0.007	0.000	-0.019	0.000
Class	q2000	0.2296	-0.019	0.000	-0.024	0.000
Office	q2000	0.1492	-0.002	0.033	-0.015	0.000
Other	q2000	0.0858	0.006	0.009	-0.016	0.000
Group	Dependent	AdjR2	D	DP	ED	EDP
All	q3000	0.0729	-0.003	0.000	-0.006	0.000
Class	q3000	0.1706	-0.009	0.000	-0.007	0.000
Office	q3000	0.0639	0.000	0.615	-0.004	0.000
Other	q3000	0.0331	0.002	0.222	-0.006	0.000
Group	Dependent	AdjR2	D	DP	ED	EDP
All	q5000	0.0250	-0.001	0.000	0.000	0.249
Class	q5000	0.1107	-0.002	0.000	0.000	0.654
Office	q5000	0.0451	0.000	0.002	0.001	0.000
Other	q5000	0.0036	0.000	0.955	-0.001	0.043

Figure 22 shows the values for the iDAq values in the high range. The R^2 values get steadily lower as the illuminance threshold rises and the significance of the variables falls, however, over all these equations continue to predict that more light at the indicated threshold is better. There are two equations where there are significant variables with positive beta—Other for q2000 and Office for q5000— however both have conflicting betas for the other half of the equation and very low R^2 values overall.

The regressions were also run in “reverse”, using the simulation outcomes to predict the occupant response to Question D. Because n=61 for these equations, the R^2 value is substantially less, and cannot be compared between the two types. This approach allowed the project team to test combinations of simulation outcomes to predict the combined (unweighted) expert and occupant response.

Figure 23: “Reverse” Regressions for Question D

Group	Dependent	AdjR2	q500	q500P		
All	D	0.0503	-2.109	0.000		
Class	D	0.1282	-2.770	0.000		
Office	D	0.0277	-1.989	0.000		
Other	D	-0.0001	0.438	0.339		
Group	Dependent	AdjR2	q500	q500P	q5000	q5000P
All	D	0.0596	-1.848	0.000	-14.589	0.000
Class	D	0.1710	-2.074	0.000	-32.331	0.000
Office	D	0.0316	-2.008	0.000	-14.499	0.031
Other	D	-0.0014	0.507	0.289	-2.370	0.617
Group	Dependent	AdjR2	q500	q500P	q3000	q3000P
All	D	0.0501	-1.998	0.000	-0.724	0.428
Class	D	0.1356	-2.017	0.000	-4.669	0.001
Office	D	0.0328	-2.706	0.000	6.256	0.016
Other	D	-0.0018	0.392	0.448	0.273	0.847

Figure 23 shows that there is an improvement in R^2 values by adding an upper value to the equation (from 0.05 for just DAq500, to 0.06 with both DAq500 and 5000) however, the direction of both predictions is in the same direction. In other words, adding more sensor*hours at 5000 lux increases occupant satisfaction with the illumination levels. This is the opposite of the intent of previously defined metrics such as Daylight Saturation Percentage, UDI and DAmax (discussed in Section 4.1.4) that assume that the higher levels of illumination will be a negative predictor.

It is possible that the sample of 61 spaces simply did not include sufficient examples of spaces at the extreme end of overly daylit spaces where an “upper limit” could better be detected. The reader is referred to the images of spaces included in Appendix D.3 for those spaces at the top end of the scale in Figure 23 (such as sfo6.2) to evaluate the quality of the most extreme conditions included in the study sample. All of the spaces were inhabited, implying that they were successfully inhabitable, and therefore probably did not violate the most fundamental principles of visual quality. Thus, it may be that a field study of real, inhabited spaces is not the right methodology for defining the upper or lower bounds of acceptable space characteristics. In this sense, this negative finding should not be taken as conclusive, but deserves further investigation using other methodologies.

Given that the addition of an upper illuminance level only amplified, rather than damping, the prediction of daylight sufficiency, the IES Committee voted to not include a second, upper value in the prediction. However, there was strong agreement that some other metric must be found that could successfully describe visual discomfort from excessive brightness, which could then be paired with the daylight sufficiency metric. The exploration for these alternatives is discussed in Section 4.2.

4.1.3 Zonal Daylight Autonomy

Moving forward the IES DMC defined a term "Zonal Daylight Autonomy" or zDA, that reports the percentile of all sensor*hours in a space that meet or exceed the 300 lux threshold. It uses regular Daylight Autonomy, rather than inverse Daylight Autonomy. After the inversion, this is essentially a renaming of iDAp, reported above, to emphasize that the value is applied across an entire space, and using the 300 lux as the standard threshold. The project team began looking at the behavior of zDA in the various spaces, relative to blinds performance, and using it as a standard of comparison to other candidate metrics, such as those described in Section 4.1.4 and Section 4.1.5.

Figure 24: Plot of Zonal Daylight Autonomy, Plus Blinds Open and Closed

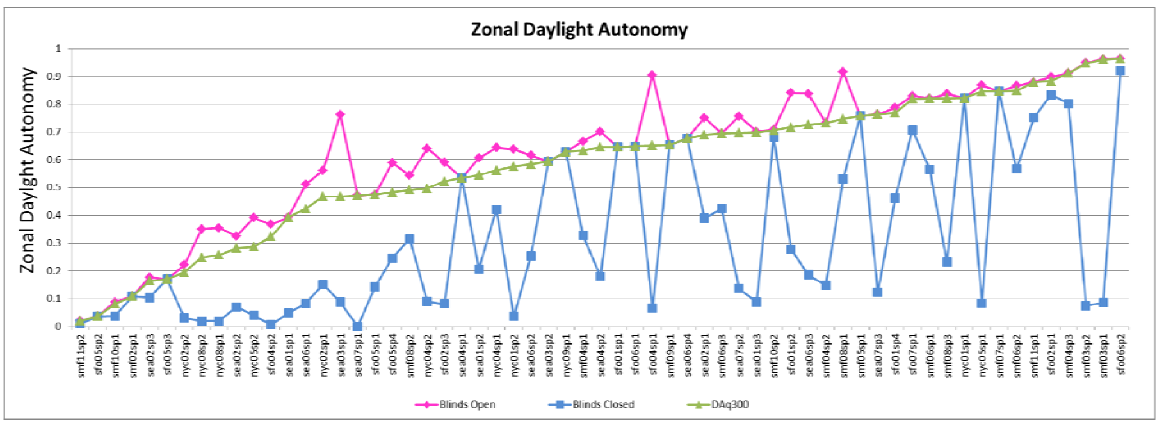


Figure 24 shows the zDA values ordered for each of the 61 study spaces, plus the corresponding values for those spaces with 'Blind Open' and 'Blinds Closed'. This is similar to the plotting of points in Figure 24, but only for the 300 lux threshold for all 61 spaces, ordered by their zDA value. The top magenta line represents Blinds Open, the green middle line represents Blinds Operated, and the blue lower line represents Blinds Closed.

4.1.4 Importance of Blinds Operation

The graph in Figure 24 is a compelling representation of the importance of the impact of blinds operation assumptions on the resulting zDA values, illustrating the range of risk for a given space, in how much brighter or darker it could get with different blinds operation schedules. The project team discussed whether as "blinds risk factor" might be developed from this information, but decided to leave that exploration for the future.

Three types of spaces could be categorized from this graph based on blinds operation:

1. those spaces that are highly dependent upon blinds to control sunlight, and which have a very large spread between magenta and blue

2. those spaces that have no dependence on blinds operation to control sunlight, but where the daylight can still be defeated with blinds left closed, and

3. those spaces that have no blinds (typically completely lit from diffusing skylights or glare-free north facing windows.

The very large differences between the Blinds Operated and the Blinds Closed cases, and the relatively smaller differences between the Blinds Operated and the Blinds Open cases, illustrates the relatively aggressive operation schedule selected for simulations in this project. However, the project team was reassured by evidence form a number of sources that this operation schedule was reasonable:

- The observation that the regressions using "Blinds Open" as the outcome variable had a better fit to the survey data than did the "Blinds Closed" version. If the opposite had been true a more conservative schedule should have been chosen for leaving the blinds closed more often.

- The finding from analysis of the occupant survey that 65 percent of occupants reported that their blinds were open at the time of the survey, and that 22 percent reported sun patches visible inside their space at the time of survey, implying that the blinds were not managed to totally block sunlight at all times.

- Observations from the site surveyors at the time of the site survey on blinds positions, which tended more open than closed.

Once again, it is important to consider that the study sample was skewed in such a way as to be inappropriate for drawing assumptions about blinds operation. While many "normal" spaces were included, many more were specifically "daylit" spaces, which may result in more thoughtful operation of blinds by the occupants. On the other hand, given that any metric derived from this study will most likely be used to define "daylit" spaces, it may be that this sample is more representative of those future spaces.

4.1.5 Other Daylight Sufficiency Metrics

The discussion below reviews the definitions of other candidate metrics, their pros and cons, and the regression findings. Some of the other proposed daylight metrics had reasonably high R^2 values, but evidenced other problems with their data structure. As mentioned earlier, these metrics can be divided into two types: single-point-in-time, and annual. The discussion below start with the currently most commonly used single-point-in-time metric, Daylight Factor.

Daylight Factor = the percentage of outdoor illumination that reaches the interior, usually measured horizontally, calculated from global diffuse illuminance on a fully overcast day.

The commonly recommended criteria is to achieve a 2 percent Daylight Factor (DF) or greater throughout a space. The DF metric generated for this analysis reported the percentage of sensors that met or exceeded 2 percent DF. The larger the area that achieved at least 2 percent DF, the more satisfied occupants were with the space.

The R^2 was relatively high, R^2=0.209, but upon further examination it became evident that the data did not have continuous linear distribution. Rather, the values tended to be either very high for those spaces where occupants were satisfied, or very low where they were dissatisfied, with little ability to predict subtle gradients in between. It became apparent that the R^2 was being driven by the highest values, generally for skylit spaces and the lowest values, with a poor fit in the middle range. This is a fundamental problem of linear regressions, which are easily tipped by extreme values, somewhat like a see-saw, if there is poor fit in the middle.

Figure 25: Plot of Daylight Factor V. iDAq300

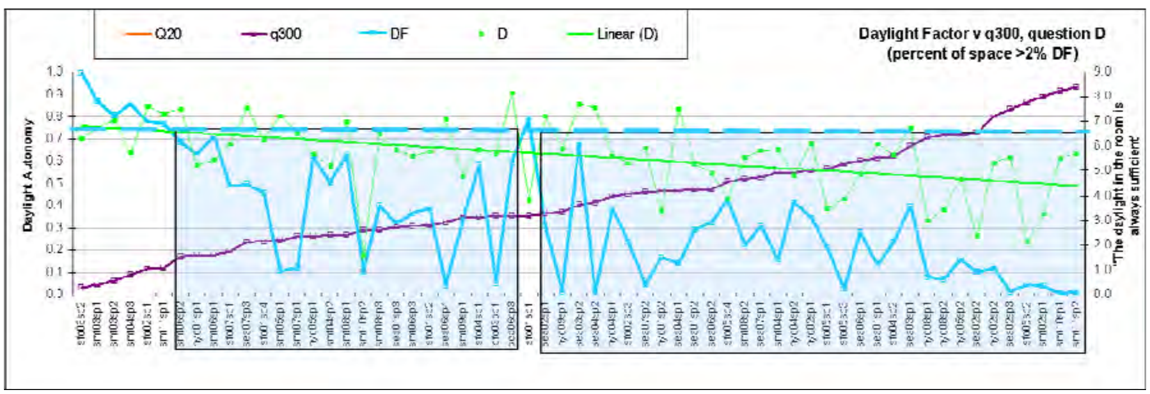


Figure 25 shows a plot of the DF Area results (heavy turquoise line) for the 61 spaces, compared to the average responses to Question D (green line with trend line added), sorted by the iDAq300 values (purple line with open square markers). The DF Area values are clearly erratic in the center of the field. A dotted line has been set at the frequently used criteria that 75 percent of the area achieves at least 2 percent DF, and then a shaded area applied over all the spaces that do not meet this criteria. Of the sample of 61 spaces, only 7 spaces passed this criteria, for example only those that were the most aggressively daylit, or SFO1sp1, which had a low transmittance but very large skylight. This is consistent with other analysis [Heschong 2006b] that has shown that the '2 percent DF for 75 percent area' criteria tends to result in over-glazed spaces in sunny climates.

LEED = percent of area that achieves 25 foot-candles at 9 am and 3 pm at the equinox, calculated on the sunniest day within 10 day of the fall equinox, with the blinds closed if needed to block direct sun.

A similar exercise was conducted for the two LEED criteria, at 9am and 3 pm local clock time. It was found that 30 spaces out of 61 passed the criteria, but that an additional 10 spaces would also have passed if only one rather than both time periods needed to be satisfied. The R^2 value for LEED at 10 am was 0.05 points higher than at 3PM, (0.17 v 0.12) suggesting that the morning criteria provides a better fit to occupants expectations, especially in classrooms and offices.

Both LEED and DF are "static" metrics that are calculated at a single point in time. As currently defined, they do not account for the dynamics of climate over the course of the year. UDI-a, DSP and Max DA are also discussed previously, under the section on Upper Limits. These three metrics are all "dynamic" in that they employ an annual simulation.

UDI-a Useful Daylight illuminance-achieved, is defined as the percent of sensor*hours between the ranges of 100 to 2500 lux. The R^2 for this metric was the lowest of the Daylight Sufficiency group, R^2=0.05, largely driven by a very low value for classrooms. It performed much better for offices (R^2= 0.23) and Other (R^2=0.20). See the discussion about high illuminance levels, such that are excluded from this calculation, in Section 4.1.2.

DSP, or Daylight Saturation Percentage, is defined as the percent of sensor*hours greater than 400 lux, while subtracting twice the percentage greater than 4000 lux. It was originally defined for use in the Collaborative for High performance Schools (CHPS) program. It achieved an overall R2 similar to that of LEED 10 am, R^2=0.18. However, it performed very poorly for classrooms (R^2=0.082) and very well for Offices and Other (both R^2=0.37).

The poor performance of both UDIa and DSP in classrooms would seem to be associated with occupants' preferences for very bright spaces in schools, while both metrics disadvantage spaces with high daylight illumination levels.

DAmax is defined at 10 times the target illumination for a space. For this project, it was calculated it as 1000, 2000, 3000 or 5000 lux. In general, regressions for all these values predicted higher satisfaction, rather than dissatisfaction, on Question D, daylight sufficiency. The R^2 values for DAmax at 5000 lux versus Question D are shown above in Figure 28. Later analysis will also show that DAq5000 did also not predict visual discomfort as gauged by Question F.

cDA , or continuous Daylight Autonomy, was defined at DA at 500 lux, plus proportional credit for any hours of illuminance below 500 lux. cDA was inadvertently not included in the nested regressions. However, it was not expected to provide more useful information than individual metrics at lower thresholds, based on the examination of data, as shown in Figure 17 and yet it required substantially more complex calculations. Because data was added across illuminance values, two spaces could potentially have very similar cDA values and yet very different performance. Figure 31 also shows that it would be expected to perform very similarly to zDA at 300 lux.

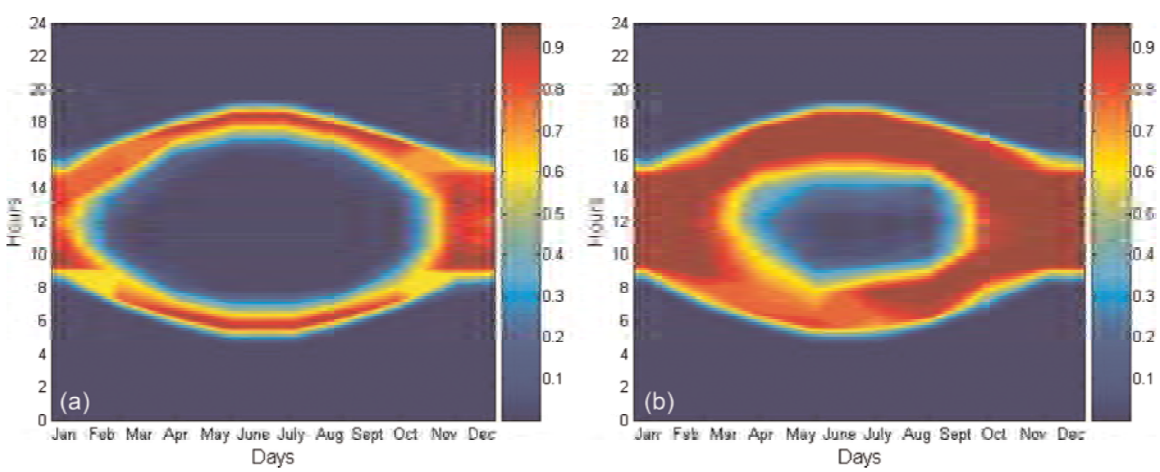
4.1.6 Spatial Daylight Autonomy

Zonal Daylight Autonomy, or DAq300, discussed earlier, was based on analysis of all sensors*hours in the dataset. This produced one value for any space, but required that the limits of the space be pre-defined. The IES DMC was interested in understanding if the daylight sufficiency analysis could be applied to spatial plots of the studied spaces, or even more importantly, to evaluate newly designed buildings, where individual rooms had not yet been defined. They explored the idea of "coverage" or how much of an area achieved a pre-set level of daylight. This approach would allow the results to be plotted on a floor plan, without pre-determining the limits of the analysis space. This request from the IES DMC led to the analysis below.

There are basically two ways to break "sensor*hours" into its component parts:
A.) for any given hour, how many sensors concurrently meet the criteria (≥ 300 lux), or
B.) for any given sensor, how many hours meet the criteria (≥ 300 lux) ?

Approach A is essentially the approach of the single point in time analysis, such as previously describe for LEED 9 am and 3 pm. It asks the question: "at 9 am on Sept 21st, how much of the room meets or exceeds 300 lux?" Alternatively, it might ask what is the average (or maximum) intensity of illumination in a given space or zone for each hour. This information can be summarized into one value per hour for each zone and presented in a temporal map, such as has been proposed by Marilyne Anderson, in [Andersen 2008] and illustrated in Figure 26 below. The original caption for Figure 26 from the paper explains: "Comparison of time-varied performance between design iterations a and b: (a) unacceptable performance most of the time, except in the middle of the winter; and (b) greatly improved performance, except in the summer from late morning to early afternoon." Similar to the bounded concept of Useful Daylight Illuminance achieved (UDIa), this temporal plot shows the percentage of all sensors are between 500 lux and 2000 lux, with additional partial credit assigned above 300 lux or below 5000 lux, for each hour of the year.

Figure 26: Temporal Plot of Annual Illuminanace Patterns



Source: Andersen 2008

While this approach has the advantage of conveying WHEN the objective is achieved, it cannot easily convey WHERE the objective is achieved, which is essential information for any architectural designer.

Approach B instead sums the hourly results for a full year for each sensor, and thus allows the number to be plotted on the floor plan as iso-contours of percent of analysis time. Thus, this approach preserves geometrical information, yet still allows for reporting by percent time or percent area. The key difference is the conditions do not happen concurrently, but rather are a separate yearly summation for each point.

Figure 27: Example of Spatial Daylight Autonomy Plot

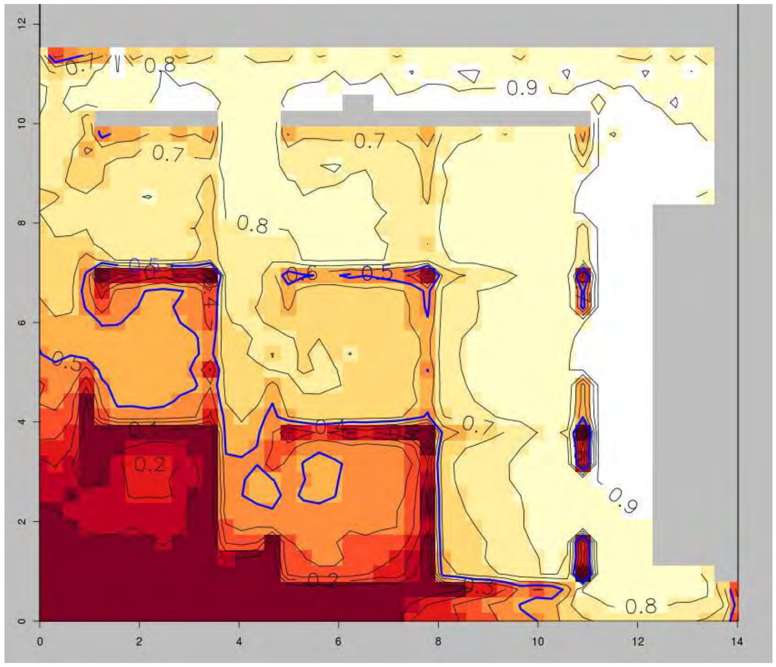


Figure 27 illustrates Daylight Autonomy, 300 lux, values for Blinds Operated per sensor plotted on the floor plan of a space which has west-facing view windows along the top edge, and a lightwell to the right (SEA6sp2). It is easy to note that that the light well is providing more light over the course of the year than the view windows. The influence of office partitions is very apparent. A blue line emphasizes the 50 percent DA contour line, which encloses both some darker 'islands' and brighter 'lakes'.

In response to the request from the IES DMC, HMG ran a new set of regressions breaking down the data by the percent of time that DA_{300} was achieved for each sensor, using the same 300 lux threshold as before. The regressions asked the question: "what percentage of the area of the study space needs to be daylit at or above 300 lux at least x percent of the time for experts and occupants to be satisfied with the daylight sufficiency of the space?" Nested regressions were run for the whole 61 spaces and the three study space types for 10 percent increments of time thresholds, from 10 percent or more of the time to 90 percent or more of the time. Thus, there were nine sets of four regressions, or thirty six new equations. These 36 regressions are shown in the large table in Figure 29 on the following page, with the highest R^2 value for each space type highlighted in bold. (In addition to the information included in the regressions presented previously, these also include the equation intercept value, so that the predictions can be calculated.)

The Other space type had the best fit at 10 percent+ of time, Offices at 60 percent+ time and Classrooms at 80 percent+ time. The best fit overall for the 61 spaces was the 50 percent+ time equation. Many of these regressions were found to have an R^2 of equivalent predictive power as the previous zonal DA_{300} equation. For example, Figure 28 below compares the R^2 values for the 50 percent time equation (which had the highest overall R^2 for “All” spaces) to those for the zonal DA_{300} equation. The differences between the two sets are very small.

Figure 28: Comparison of $sDA_{300,50\%}$ to zDA

Group	DAq300	DAarea50	diff
All	0.202	0.210	0.008
Class	0.174	0.161	-0.013
Office	0.357	0.366	0.009
Other	0.398	0.456	0.057

sDA Selection: After some discussion, it was agreed to use the 50 percent time as the single reporting method for Spatial Daylight Autonomy, both for the strength of the regression equation for the 61 spaces considered together in the ALL condition, and the simplicity of remembering 50 percent as the time threshold.

This value has been named ‘spatial Daylight Autonomy’, since the value is expressed in the percent of space. It is abbreviated $sDA_{300,50\ percent}$ with the subscript ‘300,50 percent’ to indicate the value is calculated at 300 lux for 50 percent of the yearly analysis period (for example 1825 hrs per year). For the space shown in Figure 27 about 66 percent of the sensors achieved 50 percent DA_{300} or better, thus $sDA_{300,50\%}$=66 percent.

Figure 29: Regressions for Spatial DA

Group	Dependent	AdjR2	Intercept	D	DP	ED	EDP
All	DAarea10	0.180	0.542	0.019	0.000	0.033	0.000
Class	DAarea10	0.122	0.610	0.036	0.000	0.006	0.017
Office	DAarea10	0.296	0.524	0.006	0.014	0.047	0.000
Other	DAarea10	**0.527**	0.426	0.007	0.008	0.065	0.000
Group	Dependent	AdjR2	Intercept	D	DP	ED	EDP
All	DAarea20	0.185	0.478	0.021	0.000	0.037	0.000
Class	DAarea20	0.140	0.528	0.042	0.000	0.008	0.004
Office	DAarea20	0.310	0.475	0.006	0.020	0.051	0.000
Other	DAarea20	0.524	0.358	0.004	0.134	0.073	0.000
Group	Dependent	AdjR2	Intercept	D	DP	ED	EDP
All	DAarea30	0.188	0.422	0.022	0.000	0.041	0.000
Class	DAarea30	0.143	0.460	0.046	0.000	0.011	0.001
Office	DAarea30	0.331	0.414	0.006	0.021	0.057	0.000
Other	DAarea30	0.510	0.316	0.002	0.567	0.077	0.000
Group	Dependent	AdjR2	Intercept	D	DP	ED	EDP
All	DAarea40	0.198	0.353	0.023	0.000	0.045	0.000
Class	DAarea40	0.149	0.374	0.049	0.000	0.016	0.000
Office	DAarea40	0.357	0.336	0.007	0.014	0.064	0.000
Other	DAarea40	0.486	0.285	0.000	0.891	0.079	0.000
Group	Dependent	AdjR2	Intercept	D	DP	ED	EDP
All	DAarea50	**0.210**	0.285	0.025	0.000	0.049	0.000
Class	DAarea50	0.161	0.281	0.052	0.000	0.023	0.000
Office	DAarea50	0.366	0.269	0.009	0.003	0.066	0.000
Other	DAarea50	0.456	0.259	-0.001	0.774	0.079	0.000
Group	Dependent	AdjR2	Intercept	D	DP	ED	EDP
All	DAarea60	0.208	0.211	0.025	0.000	0.051	0.000
Class	DAarea60	0.164	0.203	0.053	0.000	0.027	0.000
Office	DAarea60	**0.372**	0.172	0.011	0.000	0.067	0.000
Other	DAarea60	0.385	0.247	-0.005	0.200	0.076	0.000
Group	Dependent	AdjR2	Intercept	D	DP	ED	EDP
All	DAarea70	0.182	0.153	0.024	0.000	0.050	0.000
Class	DAarea70	0.182	0.107	0.056	0.000	0.033	0.000
Office	DAarea70	0.321	0.099	0.012	0.000	0.064	0.000
Other	DAarea70	0.266	0.288	-0.017	0.000	0.065	0.000
Group	Dependent	AdjR2	Intercept	D	DP	ED	EDP
All	DAarea80	0.125	0.084	0.022	0.000	0.045	0.000
Class	DAarea80	**0.212**	-0.028	0.058	0.000	0.040	0.000
Office	DAarea80	0.226	0.023	0.014	0.000	0.055	0.000
Other	DAarea80	0.104	0.345	-0.033	0.000	0.041	0.000
Group	Dependent	AdjR2	Intercept	D	DP	ED	EDP
All	DAarea90	0.084	-0.009	0.019	0.000	0.030	0.000
Class	DAarea90	0.161	-0.141	0.051	0.000	0.035	0.000
Office	DAarea90	0.082	0.037	0.003	0.236	0.026	0.000
Other	DAarea90	0.097	0.175	-0.021	0.000	0.026	0.000

Figure 30 : Spatial Daylight Autonomy, Plus Blinds Open and Closed

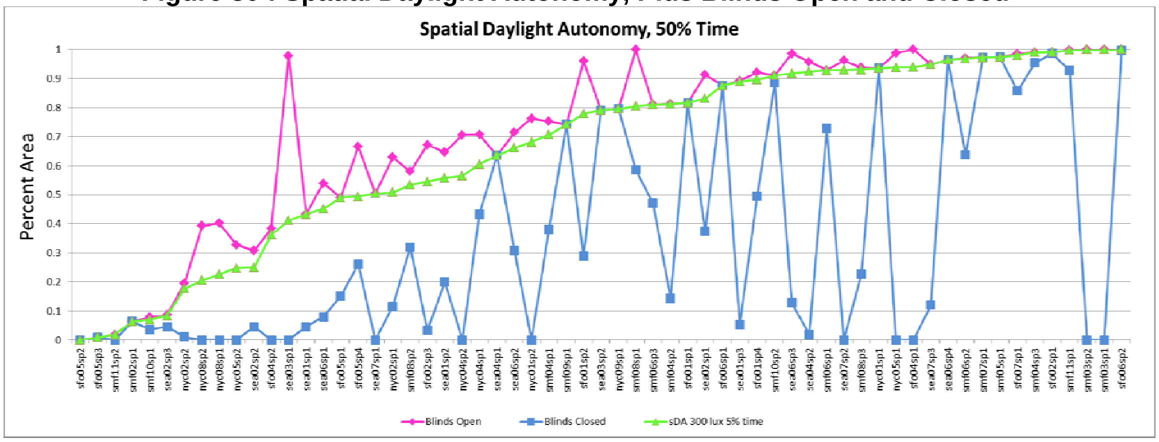
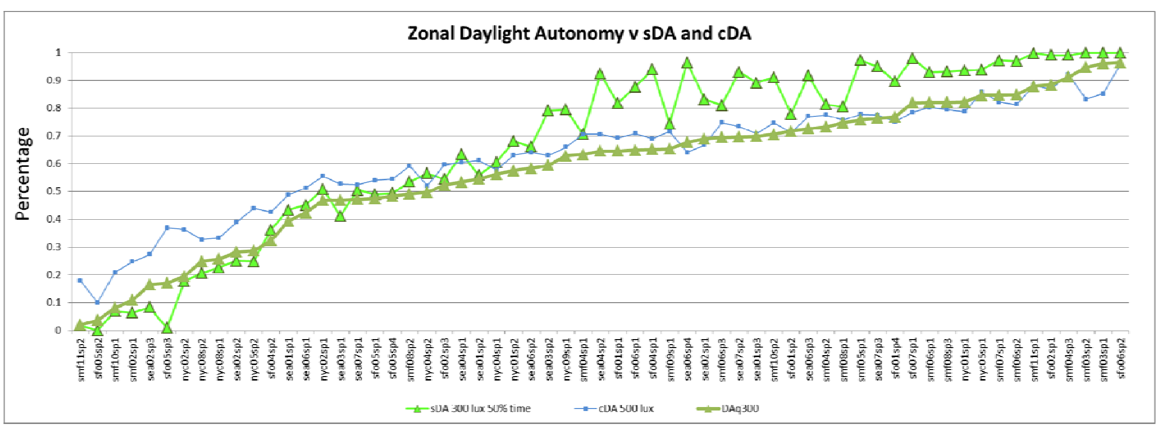


Figure 30 is a plot for $sDA_{300,50\%}$, similar to Figure 24 for Zonal Daylight Autonomy (zDA), also showing values for 'Blinds Open' and 'Blinds closed'. The vertical axes are different—Percent Area for sDA and Percentile of Sensor*Hours for zDa—and the values vary considerably, especially for the "blinds Open' and "blinds close' cases. The actual ordering of spaces is also slightly different between the two methods.

To illustrate the difference between the two methods, Figure 31 shows the ordering of spaces by Zonal Daylight Autonomy (zDA q300), and the corresponding values for each space for $sDA_{300,50\%}$ (larger triangles). This comparison shows that at the lower on half of performance the two metrics are extremely similar. From about 50-75 percentile of spaces the ordering fluctuates, while at the top 75-100 percentiles, the ordering is again very consistent.

Figure 31: Comparison of Zonal DAq300 to sDA and cDA



Incidentally, Figure 31 also shows the values of spaces calculated for continuous Daylight Autonomy at 500 lux, (light blue line) which are also extremely similar to DAq300, diverging progressively more at the bottom end. This is to be expected, given that continuous DA gives partial credit for illuminance below the threshold, for example in this case, 50 percent credit for 250 lux.

4.2 Visual Comfort Proxies

The best predictor of glare and visual discomfort was found to be a combination of the two questions "The daylight in this room is never too bright" and "I am able to do my work here without any problems from glare or troubling reflections." These two questions were highly correlated, and strongly negative responses tended to predict spaces with the least daylight. These two questions were combined together into 'Question F' which was used to evaluate which metrics could best predict visual discomfort.

In the early investigations a large number of outcome metrics were tested, described in Section3.2.2, grouped into five categories: high illuminance, building characteristics, sky view, uniformity, annual sun exposure.

Of these, the high illumination levels consistently predicted less glare, not more, as so were rejected as potential glare proxies. For simple building characteristics, single orientation had no significance. Specifically it was found that a skylight yes/no variable to the regressions did substantially improve the R^2 for almost every equation tried, generally increasing satisfaction with either Question D or F in the presence of skylights. However, it made the equations much more difficult to interpret. Furthermore, it was unclear what properties of the skylights were adding to the visual quality of the spaces—more illuminance? More uniformity? Reduction in view contrast? Longer hours of daylight? All of the above?—and it was decided that those issues should be investigated independently rather than using skylights as a proxy for some unknown value. As mentioned earlier, other building characteristics were not pursued as viable metrics for this analysis, since the purpose of the project was to identify metrics derived from annual simulations. However, the data structure would support further analysis in the future to assess the value of various prescriptive descriptions of well-daylit spaces.

For sky view, *LowMed*, performed the best of the candidates, but still had a very low R^2 of 0.02. For annual sun exposure, *nHours* did only slightly better at 0.05. The initial uniformity options also did not yield very compelling results. It was resolved to continue the investigation and look for better metrics with higher predictive values.

Given that *nHours* was the best option to date in predicting Question F, glare, other metrics were considered derived from the sun penetration data. Six new candidate metrics were tested for sun penetration, with two sensor grids and two threshold levels, described further below in the Section 4.2.2 "Sun Exposure". Likewise a few new uniformity metrics were tested using task-level illuminance values for uniformity analysis, in addition to the eye-level data tested in the initial investigations. The findings of final regressions for Sky View, Uniformity and Sun Exposure are described below.

4.2.1 Sky View

Based on the initial investigations, the sky view metric with the most promise was the low to medium mean sky view, 0-60 degrees, labeled *LowMedMean*, which consistently predicted Question B "I like the view I have from the window" and "I think the view out of the window is big enough." It is important to note that this metric *LowMedMean* described the average percentage of the skydome visible throughout the space, *not the size of the windows*. Since the 3D models included exterior obstructions from buildings and trees, very large windows could have had a very small sky view.

Figure 32: Regression of View against Questions F, Glare

Group	Dependent	AdjR2	F	FP	EF	EFP
All	LowMedMean	0.0232	-0.006	0.728	0.152	0.000
Class	LowMedMean	0.0610	-0.020	0.503	0.303	0.000
Office	LowMedMean	0.0614	0.107	0.000	0.128	0.000
Other	LowMedMean	0.0376	-0.212	0.000	-0.028	0.440

Figure 32 shows that the regression results for Question F as the explanatory variable and *LowMedMean* as the dependent variable were quite weak (ALL $R^2 = 0.02$), but with only the experts found significant for All the spaces together (column EFP). Even more interesting is the flip in beta values from positive to negative between space types or experts v occupants. Only in the Office space type did the two agree with significance, where the regression predicts that the larger the view of the skydome from horizon to 60 degrees, the more likely both occupants and experts were to <u>agree</u> with the statements of Question F "The daylight in this room is never too bright" and "I am able to do my work here without any problems form glare or troubling reflections." In other words, the bigger the view of the sky, the less glare.

Figure 33: Regression of View against Questions F, Glare and B, View

Group	Dependent	AdjR2	B	BP	EB	EBP	F	FP	EF	EFP
All	LowMedMean	0.2745	0.115	0.000	0.415	0.000	0.042	0.013	0.152	0.000
Class	LowMedMean	0.4772	0.286	0.000	0.603	0.000	-0.024	0.302	0.091	0.002
Office	LowMedMean	0.1658	0.086	0.006	0.190	0.000	0.145	0.000	0.145	0.000
Other	LowMedMean	0.2863	-0.058	0.129	0.487	0.000	-0.138	0.002	0.057	0.128

Figure 33 on the other hand, shows much stronger results (ALL $R^2 = 0.27$) when Question F was considered simultaneously with Question B, "I like the view I have from the window" and "I think the view out of the window is big enough." This results is especially strong for the Classroom space type ($R^2 = 0.48$). In this case, only the statements which positively correlate with the outcome are significant, again, reinforcing the association of bigger views with better views and less glare, with one exception, that for occupants reporting on the glare in Other spaces (column FP), so for them (but not the experts), where in that case larger windows mean more glare.

The strength of this regression suggests that there is likely collinearly between Questions B and F. However, this was not tested: since this metric was not predicting increased glare, it was not pursued further.

4.2.2 Uniformity

The project team hypothesized that some measure of illuminance uniformity would correlate to occupant visual comfort, aesthetic rating, or assessment of daylight sufficiency.

Uniformity Analysis

The original intent of the ceiling plane sensor grid was to be able to quantify daylight uniformity in the space. The assumption was that the ceiling grid could serve as a proxy for the upper visual horizon. A number of tests were done on the data from the ceiling grids:

The following uniformity metrics, examining illuminance data form the ceiling grid for the Blinds Operated case were initially considered:

- ***CV***, coefficient of variation (standard deviation/norm) of annual hourly ceiling plan illumination
- ***IQR***, hourly interquartile range (25-75) of annual hourly ceiling plane illumination
- ***IDR***, interdecile range (10-90) of annual hourly ceiling plane illumination
- ***MM,*** yearly maximum of hourly minimum to maximum ratio
- ***MaxTenNinty,*** ratio of tenth percentile to ninetieth percentile of hourly minimum to maximum ratio
- Plus, ***90th percentiles*** and ***Medians*** of above were also run
- The prefix ***h*** was added to those metrics analyzed per hour, as in: compile the statistics first for the ceiling plan for each hour, and then process the annual statistical values.

None of them were found to correlate well to occupant visual comfort.

Similar metrics based on the task-level illuminance data were also tested, in the hopes of both simplifying the simulation methodology, and finding a better fit. Indeed, the regressions using the task level data did show a slightly better fit, and yet still were not very compelling. Given this, the project team was convinced that the ceiling grid was not obviously a better candidate for uniformity analysis, and so recommended that the ceiling grid could be dropped from the standard simulation methodology to simplify modeling and speed up the simulations.

Figure 34: Task Level Uniformity Regression Analysis

1	Group	Dependent		D	DP	ED	EDP	EG	EGP	skylight	skylightP
	All	h90CV	0.1157	0.044	0.000	-0.086	0.000	0.029	0.008	-0.293	0.000
	Class	h90CV	0.1055	0.070	0.000	-0.092	0.000	0.057	0.010	-0.338	0.000
	Office	h90CV	0.2856	-0.005	0.339	-0.079	0.000	-0.012	0.125	-0.040	0.145
	Other	h90CV	0.1386	0.056	0.000	-0.119	0.000	0.038	0.186	-0.394	0.000
	Group	Dependent	AdjR2	D	DP	ED	EDP	EG	EGP	skylight	skylightP
2	All	h90IQR	0.0231	12.161	0.000	5.581	0.290	13.186	0.020	-95.894	0.000
	Class	h90IQR	0.2362	65.278	0.000	-5.922	0.408	26.213	0.001	-63.925	0.000
	Office	h90IQR	0.0064	-8.640	0.114	5.886	0.481	-15.617	0.099	79.135	0.012
	Other	h90IQR	0.2791	-25.093	0.000	52.913	0.000	23.340	0.014	-359.616	0.000
3	Group	Dependent	AdjR2	D	DP	ED	EDP	EG	EGP	skylight	skylightP
	All	h90IDR	0.0474	33.575	0.000	-19.231	0.114	95.702	0.000	-150.103	0.000
	Class	h90IDR	0.2051	149.198	0.000	-37.121	0.071	136.597	0.000	-49.888	0.321
	Office	h90IDR	0.0141	-19.176	0.061	-42.561	0.007	12.580	0.478	173.165	0.003
	Other	h90IDR	0.1542	-72.737	0.000	91.815	0.001	65.522	0.012	-411.977	0.000
4	Group	Dependent						EG	EGP	skylight	skylightP
	All	h90CV	0.0724					-0.043	0.000	-0.295	0.000
	Class	h90CV	0.0441					-0.030	0.002	-0.303	0.000
	Office	h90CV	0.1999					-0.074	0.000	-0.093	0.001
	Other	h90CV	0.0932					-0.052	0.001	-0.409	0.000
5	Group	Dependent	AdjR2					EG	EGP	skylight	skylightP
	All	h90IQR	0.0204					18.269	0.000	-102.921	0.000
	Class	h90IQR	0.0223					18.677	0.000	-83.345	0.000
	Office	h90IQR	0.0105					-14.765	0.032	98.452	0.001
	Other	h90IQR	0.2336					62.051	0.000	-347.818	0.000

For both ceiling level and task level analysis ***h90CV***, or the 90th percentile of coefficient of variation, had consistently shown the best, if still weak, performance. **h*90IQR*** and **h90IDR** were the next best. Figure 34 above shows results from the final round of regression equations, using task level illuminance, and focusing on the three strongest metrics. The presence or absences of skylights was found to be consistently significant, and so was kept in the equations. In addition to Question D, 'daylight sufficiency' Question G "uniformity' was added to the equation, or tested by itself (column EG is the beta value for the experts' response to Question G and EGP is the probability that variable is significant.) Question G was only asked of the experts, and so has a much smaller response than Question D.

Data from Figure 34 shows that the behavior of these equations are not very stable. The beta values flip between positive and negative, and while the variables are mostly significant, the R^2 values are generally low, especially for the group taken as a whole. Indeed, most of the explanatory power is coming from the skylight yes/no variable and secondarily from Question G. The Office space type seems to perform differently than the Classroom or Other types in these tests, thus it might be appropriate to have a different uniformity standard for offices than the two other space types.

Overall, the project team concluded that the range of uniformity metrics tested were not sufficiently promising for further analysis. It would be possible, however, to continue the uniformity investigation with the existing data set, but using other analysis methods, as discussed below:

Uniformity Discussion

Electric v Daylight Uniformity: Existing electric lighting uniformity metrics, such as min/max ratios or avg/min ratios have underlying assumptions about the quantum spacing of the electric lighting fixtures, such as pole spacing for outdoor lighting, or center to center spacing for interior grids. Thus, all electric lighting uniformity specifications have an implied spatial dimension and corresponding gradient. Daylight gradients, on the other hand, are typically a function of window or skylight spacing, and/or the depth of the entire room, and as such, tend to be much larger and more variable. The project team is not aware of any studies on the acceptability of various daylight gradient to occupants, or preferred methods to describe daylight variability. Many practitioners have reported that the common guidelines from electric lighting, such as keeping luminance ratios within 1:10 or 1:20 are overly conservative for daylit spaces, where occupants have much higher tolerance for variability.

Other metrics seem possible, especially those looking a spatial discontinuity. Fourier analysis has been proposed as a way to describe harmonic relationships into their component parts, and the distinctiveness of edges around pools of illuminance. Since daylight illuminance has a spatial period determined by the location of each aperture, and these will interact, Fourier analysis might have some merit. However, Fourier analysis has been used primarily to look for patterns over time, rather than 2D space.

Spatial Statistics: In the comparatively newer field of spatial statistics or "geostatistics", that is specifically directed at detecting patterns over space and/or time. A number of analysis tools are available, such as correllograms that describe how correlated a value is at various spatial separations, comparing the correlation of each point to all other points in the space. Uniformly daylit spaces would be expected to have very highly correlated values across large areas. Correlations can be studied across both space and time. Variograms are another method of describing spatial dependence, looking at the absolute values within the spatial data.

Computer Vision: In the area of computer vision, 'blob detection' refers to visual modules that are aimed at detecting points and/or regions in the image that are either brighter or darker than the surrounding, and then tracking changes over time. Given that computer vision deals with light intensity, space, type and changing patterns, it is likely that the field could provide some very useful tools applicable to describing daylight uniformity for analysis, and comparison to subjective human evaluations.

Future analysis: It could be possible to test some of these spatial statistics on the simulation data set used for this study, since the data has been preserved in fine detail of resulting illuminance intensity by sensor by hour. Luminance data is not available at this time, but could potentially be generated in the future using the same 3D models and climate data.

4.2.3 Annual Sun Exposure

In the initial simple regression analysis, the most promising metric in predicting Question F (glare) was sun penetration ***nHours.*** Given that finding, it was decided that further investigation of alternative sun penetration metrics was warranted. The discussion below describes the new variables considered.

Definition of Sunlight: Hourly sunlight penetration into the study spaces was studied using only direct solar radiation (defined as zero bounces in the Radiance scripts), per the local weather files, projected though the fenestration, and accounting for all exterior shading, and interior furniture and glazing, but not for blinds operation. It is important to note that no contributions from diffuse skylight or inter-reflections contributed to the values. The hourly simulations reported continuous illuminance values, ranging from 1 lux to 10,000 lux, at the eye-level sensor grid.

Threshold Selection: Two levels of interior sunlight illumination, 1000 lux and 4000 lux, were compared for their ability to predict experts' and occupants' glare assessment, as judged by the combined Question F ("The daylight in this space is never too bright" and "I can do my work here without any troubling glare or reflections"). It was found that using the 1000 lux threshold as the definition of sunlight provided a slightly better prediction of the experts' and occupants' glare assessment across all candidate metrics.

Independent field measurements by Lisa Heschong and Rick Mistrick reinforced the selection of this level as a perceptual threshold for the presence of direct sunlight under overcast conditions or early in the morning or late in the afternoon. It implies that there will be approximately a 1000 lux difference between adjacent field measurements in sunlight and shadow. This threshold can be interpreted as one way of answering the seemingly simple question from the simulation data: "Is the sun out?" By way comparison, it was not formulated to capture other ways that might identify glare potential, such as "Is the hour sufficiently overcast that shadowing is softened?", or "Are sun patches sufficiently bright to potentially cause contrast glare or annoying reflections?".

Grid Selection: The sun penetration metric outcomes were compared for the eye level grid versus the task level grid. The task level grid is more strongly influenced by shadowing from furniture, while the eye level grid is likely to capture information about low angle sun. It was found that the R^2 of the task level option was just slightly higher (delta R^2 = +0.02 to +0.04), even though the ordering of the spaces shifted. Thus, given the advantages of simplifying the methodology by using only one grid for all purposes (blinds operation, glare-proxy, and daylight sufficiency), it was decided to proceed forward with the task level (a.k.a. work plane) sensors.

The seven candidate sun penetration metrics chosen for further study were:

1. ***nHours*** = the number of hours when more than 2 percent of sensors exceeded the sun threshold. This is basically the number of hours that the blinds need to be operated in the space.

2. ***senHours*** = the number of sensors*hours that exceeded the sun threshold , divided by the total number of sensors in the space, reported as a percentage. This is the average number of hours in sunlight experienced by sensors in the space.

3. ***maxHours*** = the number of hours exceeding the threshold for the one sensor seeing the most hours in the space. This is the worst case condition for any sensor in the space.

4. ***q90Hours*** = the number of hours exceeding the threshold for the 90^{th} percentile sensor (excluding all zero values). This is a more common condition for high sun exposure.

5. ***maxArea*** = the maximum area in a single hour exceeding the threshold , divided by the total number of sensors in the space, reported as a percentage. This is the worst case condition for the hour with the most sensors in sunlight.

6. ***q90Area*** = 90^{th} percentile of area in single hour exceeding threshold (excluding all zero values), divided by the total number of sensors in the space divided by the total number of sensors in the space, reported as a percentage. This is a more common hourly condition for high sun exposure.

7. ***sunUnif*** = median hourly sun penetration area, divided by yearly maximum sun penetration area, reported as a ratio. This compares the average hourly area to the worst case area.

4.2.4 Findings

Of the seven metrics, *maxHours* consistently had the highest R^2, and *maxArea* second highest R^2. While *maxHours* was high for all three space types, *MaxArea* was only high for the office space type. Plotting the two metrics resulted in very different ordering of spaces.

Figure 35 : Results for 7 Sun Penetration Candidate Metrics, n=61

Group	Dependent	AdjR2	F	Fp	ExF	ExFp
All	nHours	0.0562	-14.666	0.009	-66.141	0.000
Class	nHours	0.0043	9.926	0.256	-26.937	0.009
Office	nHours	0.2094	-44.137	0.000	-111.831	0.000
Other	nHours	0.0664	-19.118	0.107	-60.689	0.000
Group	Dependent	AdjR2	F	Fp	ExF	ExFp
All	senHours	0.0841	-3.105	0.000	-8.101	0.000
Class	senHours	0.0156	-0.662	0.503	-4.670	0.000
Office	senHours	0.2317	-5.389	0.000	-13.533	0.000
Other	senHours	0.0648	-1.810	0.042	-4.371	0.000
Group	Dependent	AdjR2	F	Fp	ExF	ExFp
All	maxHours	**0.1492**	-33.608	0.000	-83.104	0.000
Class	maxHours	**0.1006**	-19.396	0.000	-56.534	0.000
Office	maxHours	0.2271	-43.034	0.000	-94.514	0.000
Other	maxHours	**0.1376**	-62.893	0.000	-105.154	0.000
Group	Dependent	AdjR2	F	Fp	ExF	ExFp
All	q90Hours	0.0937	-9.118	0.000	-30.330	0.000
Class	q90Hours	0.0339	-2.257	0.488	-22.718	0.000
Office	q90Hours	0.1850	-15.745	0.000	-42.390	0.000
Other	q90Hours	0.0974	-1.367	0.666	-20.999	0.000
Group	Dependent	AdjR2	F	Fp	ExF	ExFp
All	maxArea	0.1365	-0.012	0.000	-0.024	0.000
Class	maxArea	0.0317	-0.007	0.001	-0.009	0.000
Office	maxArea	**0.3288**	-0.018	0.000	-0.049	0.000
Other	maxArea	0.0194	0.000	0.990	-0.005	0.000
Group	Dependent	AdjR2	F	Fp	ExF	ExFp
All	q90Area	0.1261	-0.007	0.000	-0.013	0.000
Class	q90Area	0.0374	-0.004	0.000	-0.005	0.000
Office	q90Area	0.2811	-0.012	0.000	-0.026	0.000
Other	q90Area	0.0117	0.001	0.182	-0.002	0.004
Group	Dependent	AdjR2	F	Fp	ExF	ExFp
All	sunUnif	0.0027	0.000	0.034	0.000	0.141
Class	sunUnif	0.0728	0.000	0.003	0.000	0.000
Office	sunUnif	0.2764	0.000	0.000	0.000	0.000
Other	sunUnif	0.0197	0.000	0.143	0.000	0.002

Figure 35 shows the results for the regression equations for the seven candidate metrics (dependent variable) for the four groups, for example all spaces (n-61) and the three individual space types. The column labeled "F" reports the beta value for the occupants' response to Question F. "Fp" reports the probability that explanatory variable is significant. Likewise "ExF" reports the beta value for the Experts response to Question F, and "ExFp" the probability that variable is significant. Where the explanatory variable returns a positive value (>0) the cell is colored blue, indicating a contradictory result. When the probability value was not significant ($p>0.099$) that cell is colored purple. The "AdjR^2" column reports the adjusted R^2 for each equation. The red gradient gives a quick visual indication of those equations with the largest R^2. Equations which had the highest R^2 for their group are **bolded**. The *maxHours* equation has the highest R^2

for all space types combined, and the highest also for Classroom and Other. It also has no problems with inconsistent or insignificant variables across all space types.

Interestingly, the two 90th percentile options for Hours and Area were consistently weaker than comparable the Max version. Examination of the data revealed that the data was highly skewed, with big spikes at the maximum values. Thus, while the 90th percentile analysis was intended to capture a more representative upper value, it was not as predictive as the maximum value, at the top of the spike.

In addition to R^2, one of the important tests in evaluating the metrics is that the 8 explanatory variables were all consistent and significant across the set for each equation (8 variables = inputs experts and occupants (2) * space type groups (4): all, classrooms, offices, library/lobby). Other than *MaxHours*, all of the other equations had problems with stability, where some of the explanatory variables in the set would point in different directions, and problems with significance, where not all the explanatory variable would pass the significance test of $p<0.05$.

Outliers: Given the highly skewed nature of the data, and the relatively low R^2 values, it was decided to test the sensitivity of the equations to outliers or other explanations for influences on the assessment of glare. It was found that the outliers did not have much influence on the outcome of the equations, but that the spaces with unusual blinds operation did. Removing the four spaces that controlled direct sunlight with either automated blinds (NYC4.1 and 4.2) or inverted blinds (SMF8.1 and 8.2) greatly improved the precision of the equations.

Figure 36: Final Regression Results for Sun Penetration Analysis

Group	Dependent	AdjR2	F	Fp	ExF	ExFp
All	nHours	0.0819	-21.685	0.000	-63.466	0.000
Class	nHours	0.0099	-13.586	0.069	-20.415	0.025
Office	nHours	0.3977	-38.253	0.000	-118.076	0.000
Other	nHours	0.0672	-16.208	0.165	-59.408	0.000
Group	Dependent	AdjR2	F	Fp	ExF	ExFp
All	maxArea	0.1719	-0.014	0.000	-0.026	0.000
Class	maxArea	0.0790	-0.012	0.000	-0.008	0.000
Office	maxArea	0.3766	-0.017	0.000	-0.057	0.000
Other	maxArea	0.0183	0.000	0.856	-0.005	0.000
Group	Dependent	AdjR2	F	Fp	ExF	ExFp
All	maxHours	0.2025	-37.328	0.000	-84.832	0.000
Class	maxHours	0.2341	-35.652	0.000	-55.309	0.000
Office	maxHours	0.3259	-36.535	0.000	-102.370	0.000
Other	maxHours	0.1428	-60.059	0.000	-104.129	0.000

Figure 36 shows the results of three final regression equations testing candidate sun penetration metrics against Question F, with the removal of spaces with exceptional blinds operation. While the outlier tests were run for all metrics, only the three of particular interest are shown here. It was found that the *maxHours* equation consistently had the highest overall R^2, and stable and significant values for all space types and explanatory variables. Thus, this equation was chosen as the best predictor of occupant visual discomfort.

It should be noted in Figure 36 the R^2 values for *nHours* and *maxArea* also increased, most dramatically for the Office space type. Interestingly, for the first time, *nHours* has a equation with the highest R^2 for a space type, but it is dramatically different from the other two space types. The strength of both the MaxHrs and the MaxArea metric for offices suggests that some combination of frequency, intensity and area may be useful for a sun penetration metric, especially for offices. It may be that, similar to the definition of sDA, a threshold could be set for a maximum number of hours of tolerable sun exposure (see discussion below) and then report the percentage of sensors that meet this criteria. As of the writing of this report, neither the project team nor the DMC have been able to explore that concept further.

Annual Sun Exposure: The IES DMC decided to name this most promising metric – *maxHours* – as “Annual Sun Exposure”. ‘Annual Sun Exposure’ is hereby defined as the maximum number of hours per year each task-level sensor will see direct sunlight >1000 lux, given local weather conditions, exterior obstructions, glazing transmission, and interior shadowing from furniture and partitions, but with any blinds or shades left in the fully retracted position.

The translation of the equation results into occupants' preferred values is shown in Figure 37 below, reported as maximum number of sunlight hours per year for any sensor in the space, to avoid glare from sunlight.

Figure 37: Annual Sun Exposure – Regression Predictions

Likert Score	1	2	3	4	5	6	7	8	9
All	1044	922	799	677	555	433	311	189	67
Classrooms	908	817	726	635	544	453	362	271	180
Offices	1086	947	808	669	530	391	252	114	-25
Library/Lobbies	1292	1127	963	799	635	471	306	142	-22

Looking at the transition point between the blue and the green areas, Figure 37 shows that less than about 300-350 hours of sun exposure per year will result in a positive assessment (6.5), and the transition point between the tan and the green areas shows that less than about 550-600 hours per year will result in a neutral assessment (4.5).

Discussion of Annual Sun Exposure

For any sun penetration metric to work in concert with the daylight sufficiency metric, the two metrics ideally would have outcomes with the same units, such as square footage, that would enable them to be considered in a unified rating equation. However, given that the project team has not been able to do any analysis that studies how one metric influences the other, there is simply not enough information at this point in time to conjoin the two concepts. Thus, for the time being, they should be treated as two separate concepts.

The *Annual Sun Exposure* metric could be considered a modifier of the Daylight Autonomy criteria. For example, once a space has been determined to pass the Daylight Autonomy criteria, then the *Annual Sun Exposure* metric can be considered as qualifying the score, and suggesting mitigations to reduce sun exposure and improve occupant visual comfort.

An example of a progressively stringent system based on *Annual Sun Exposure* might be:

Operable blinds or shades are always recommended for transparent glazing Fto allow occupants control for privacy, security and intermittent visual discomfort from reflections or high contrast.

- Preferred (grade A) < 300 hours
- Acceptable (grade B) < 600 hours
- Provisional (grade C) > 600 hours
    - o and should include advanced fenestration systems to improve occupant visual comfort, such as automated or inverted blinds, automated shades, or sunlight redirecting systems
- Unacceptable (grade F) > 900 hours

- without advanced fenestration systems

Hours and Area: The other two equations shown in Figure 36 suggest that in addition to the maximum number of hours of sunlight which can potentially enter a space, that other dimensions may also be potentially useful in predicting occupants' glare assessment. The *nHours* metric reports the number of hours that exceed the 2 percent threshold used to operate the blinds in the simulations, or in other words the number of hours that ANY sunlight could be in the space. The *maxArea* metric reports the largest area that could ever be in sunlight over the course of the year. Both are very strong predictors for the office space type, and much less so for the other space types, suggesting that office workers may be more sensitive to these two parameters.

Space types: Experts and occupants were consistently most judgmental about glare conditions in offices space, less so in classrooms, and the least so in the library and lobby space type. This makes logical sense from at least two perspectives: fixed versus optional task locations, and permanent versus temporary occupancy. First of all, office workers have the most fixed task location, where they spend the most time per day, compared to the other types, while libraries and lobbies have more variable tasks where the location is often optional. Second of all, office workers are typically permanent staff, while library and lobby occupants are typically only occasional visitors who would have less experience with the space, and perhaps less demanding performance expectation for that space. In both cases classroom fall in the middle of the spectrum.

Orientation and blinds types: Preliminary analysis suggested that expert and occupant assessment of glare is associated with orientation and blind type. The study spaces were divided into three orientation groups:

- North facing (±30 degrees) and/or toplit,
- East and west (-60+30 degrees)
- South facing (±30 degrees)

Assessments were least likely to be negative for the first group, north facing and/or toplit spaces, and most likely to negative for east or west facing spaces, with south facing spaces ranking in between. This finding is consistent with the patterns of low angle sun or each façade type. Indeed, there was a suggestion in the regression results that some small amount of direct sunlight or the order of 100 hours per year might even preferred in north facing spaces.

For blinds types, the study spaces were divided into three blind groups:

- No blinds,
- Translucent roller shades
- Slatted Blinds (horizontal or vertical)

Glare assessment via Question F were strongest for those spaces with no blinds, and next strongest for those with translucent roller shades. The glare assessment for spaces with slated blinds was neutral, meaning that more sun penetration did not increase glare assessments for these spaces. Alternatively, it might be interpreted that the slated blinds were most successful in mitigating the visual comfort problems caused by sun penetration.

Statistical tests showed that both these distinctions (orientation and blinds) were not significantly different from each other ($p<0.05$), and therefore might not be a stable finding. However, the differences are distinct enough to suggest that further study would be warranted. Eventually, further data might enable orientation and blind condition to be additional modifying variables in a sun penetration metric.

Eventually, it may be possible to define a combined time and area rating system, such as plotting iso-contours of the number of hours of sun exposure on a floor plan and setting limits on the size for each category. One could imagine a formula combing the rating derived from the percent of floor area achieving *50 percent* $sDA_{300, 50\%}$ modified by the percent of floor area with >300 hrs of *Annual Sun Exposure*. However, any such combination of the two metrics is in the future, since there is not information at this point in time about how the two metrics interact to effect occupant comfort or preferences. Furthermore, with further research, other metrics impacting visual comfort are likely to be identified, and/or further modifications of the proposed metrics, which will improve the accuracy of any such visual comfort equation.

CHAPTER 5: Next Steps and Market Connections

With the field study of 61 daylit spaces, great strides have been made towards a future where there will be well-understood annual performance metrics for daylit spaces. The project team believes that with the development of the Dynamic Radiance approach, they have improved the prediction of annual illuminance values for daylit spaces. In the process of pursuing this field study, many methodological issues have been resolved that will be useful in defining standard procedures for defining performance metrics.

Once the final metrics have been selected by the IES, the methodology required to generate them will need to be formally defined and documented, where upon an array of professional-grade simulation tools can start to incorporate them into their standard offerings. With tools, emerging standards can define criteria based on the metrics, and professionals will be motivated learn how to apply them in their design process. Furthermore, once new analysis capabilities are adopted into commercial simulation software, such as the BSDF approach pioneered in the Dynamic Radiance approach, a market demand will be created for the testing and reporting of advanced fenestration product performance by manufacturers, so that performance data can become universally available.

The following section describes some of the specific steps that are already in progress to apply this work to codes and standards; a discussion of some of the needs for additional research; and the roles of many of the other organizations who should be involved in bringing this work to fruition. Part of the work funded by this PIER project was to ensure these "market connections" were carefully tended. Those efforts are further documented in the final report for the associated Daylighting Plus Market Connections project [Heschong 2001b].

5.1 Applying Metrics to Codes and Standards

The ultimate goal of the daylight Metrics project was to establish national or international consensus on the quantification of daylighting performance that could be implemented in daylighting requirements in codes and standards, such as building health and safety codes, energy codes, and voluntary performance standards, such as LEED, CHPS, or owner specifications.

This process is already underway, however in somewhat more chaotic fashion than might be ideal, given the urgency of the need, and the slowness of achieving widespread consensus on the subject. The Daylighting Forum, hosted in Las Vegas May 2010, partly funded by PIER through the larger Daylighting Plus program [Heschong 2010b], was a useful step in the direction towards unification of metrics, bringing together key players from around the country actively working on a variety of codes and standards.

5.1.1 Daylight Sufficiency – Spatial Daylight Autonomy

The values shown in Figure 29 for the 50 percent time equations have been translated into their resulting prediction of the percent area that would result in a given Likert score (L), using the equation [$sDA_{300,50\%}$ = intercept + (D*L + ED*L)]. The results of these equations are shown in Figure 38 below.

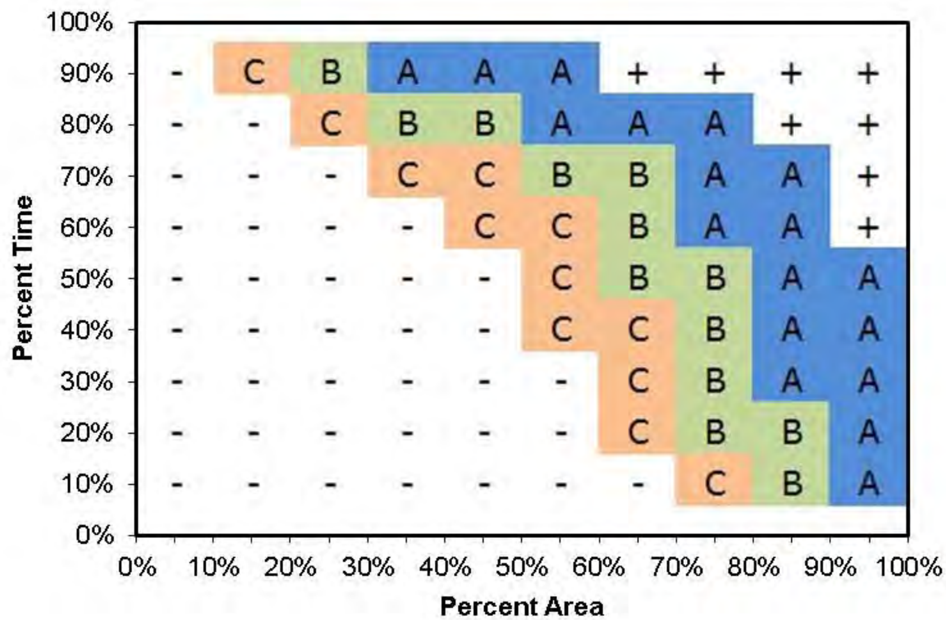
Figure 38: Prediction of Percent Area by Likert Score, per $sDA_{30,50\%}$

Grade			C	C	B	B	A	A	A
Likert Score	1	2	3	4	5	6	7	8	9
All	0.36	0.43	0.51	0.58	0.65	0.73	0.80	0.87	0.95
Class	0.36	0.43	0.50	0.58	0.65	0.73	0.80	0.88	0.95
Office	0.34	0.42	0.49	0.57	0.64	0.72	0.79	0.87	0.94
Other	0.34	0.41	0.49	0.57	0.65	0.73	0.80	0.88	0.96

The predictions of Figure 38 were then transposed into a more useful format, shown in Figure 39 which illustrates which combinations of area and time will be generally acceptable to occupants. The cells labeled 'A' achieved a Likert score of 7-9, or clearly positive, while those labeled 'B' achieved a Likert score of 5-6, or neutral, relative to the two questions included in Question D, for example "I can work happily in this room with ALL of the electric lights turned off" and "The daylight in this room is always sufficient."

Those labeled 'C' achieved a Likert score of 3-4, or slightly negative relative to Question D, and thus define the zone of un-acceptability.

Figure 39: Criteria Table for Spatial Daylight Autonomy



It is worth noting that the distribution of these values is not linear, but implies a curving function. Given the structure of the data which generated it, this table is best read from the vertical axis (percent time) to the horizontal axis (percent area). Furthermore, it should be noted that plotting an alternative version of the sensor*hour data set, such as "the percent of time that at least 75 percent of the sensors in the space currently achieve 300 lux" results in a different function.

The IES DMC reviewed this plot, and generally found it useful and easy to understand. In support of this effort, a series of plots for each study space were prepared, with the $sDA_{300,50\%}$ values generated from the simulation for the three blinds cases, were overlaid on this Criteria Table.

Figure 40: Example of sDA Plot for a Study Space

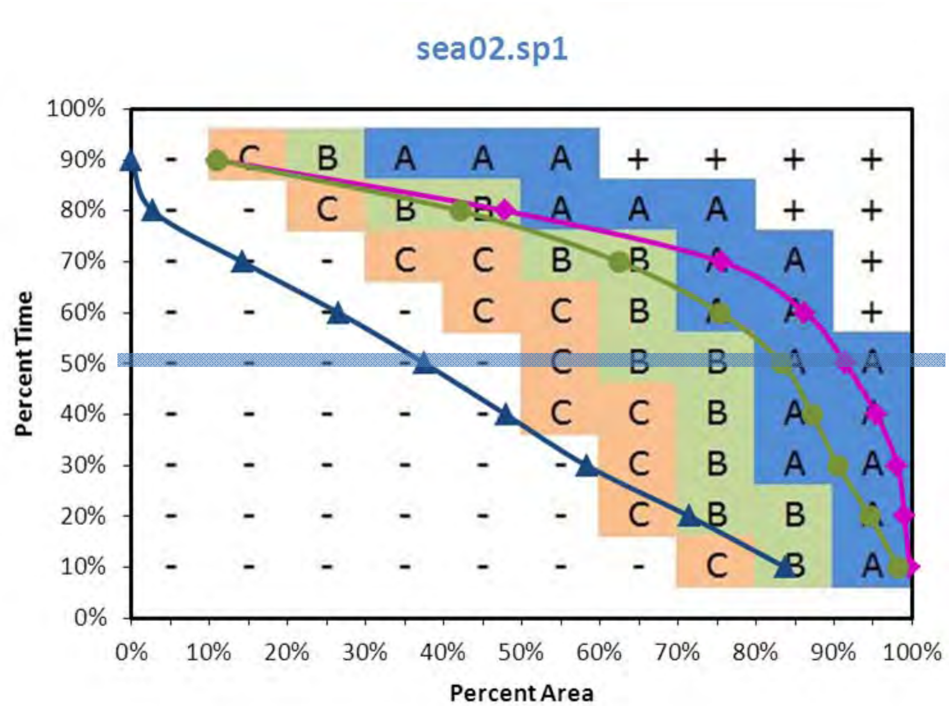


Figure 40 shows a sample of the simulation results for Study Space sea02.sp1, where the blue line w triangles shows the values for Blinds Closed, the green line with circles shows the values for Blinds Operated (note, this is difficult to see in a black and white print), and the magenta line with diamonds shows the values for Blinds Open. In addition a thick light blue line has been placed at the 50 percent time criteria, showing that this space passes the criteria with an 'A' grade for the Blinds Operated case, at 85 percent of the area achieving this goal.

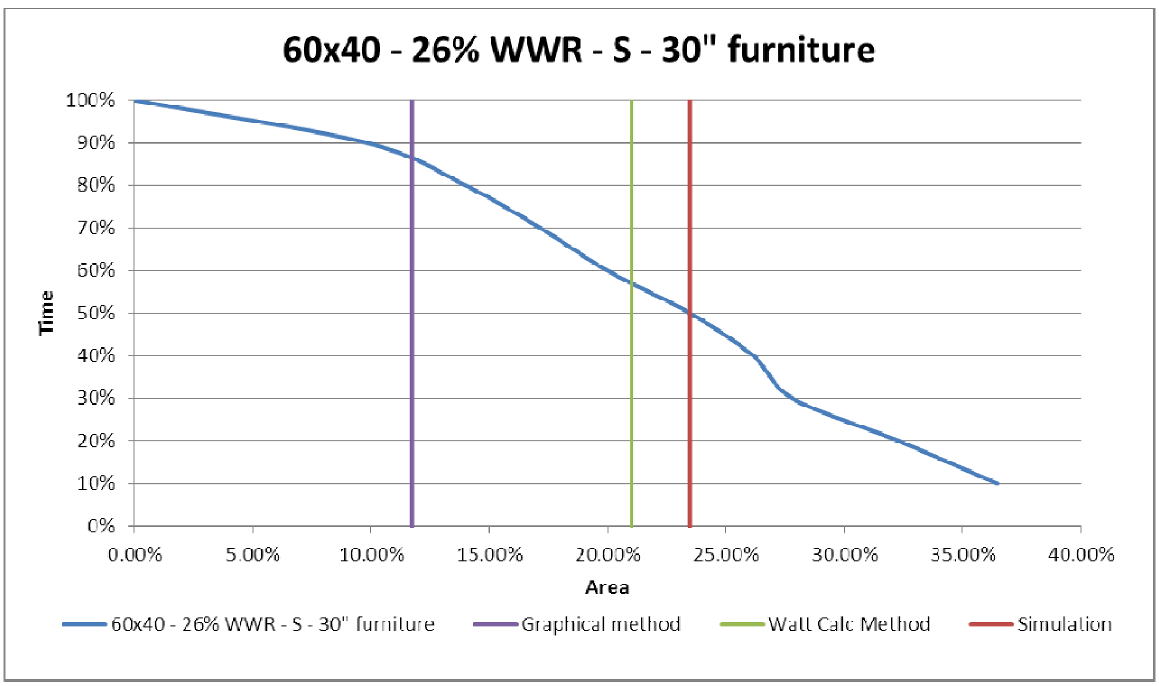
The outcome for all 61 study spaces are shown in Appendix D.2. In addition to the plot of the simulation values, the images in Appendix D.3 provide additional contextual information about each study space to add in the interpretation of the data.

It is interesting to note that the three blinds cases is not nearly as informative in this format as the previous iDAp plots, shown in Appendix 0. This seems to be attributable to the quantum effects of reporting the data with two thresholds constrained simultaneously—both the illuminance threshold of ≥300 lux and the time threshold of ≥50 percent—compared to the continuous illuminance data presented in the iDAp plots. Since there are two threshold conditions that must be passed on a yes/no basis, and the only continuous information provided is percent of area covered, the $sDA_{300,50\%}$ plots have much bigger discontinuities among the three blinds conditions.

Code Applications: In anticipation of the IES DMC recommending adoption of this metric, the $sDA_{300,50\%}$ metric was applied to recent analysis in support of new Title 24 regulations for wattage to be controlled by photocontrols in daylit areas [CASE 2011] using the Level One analysis. The analysis created a simplified calculation that approximated that savings that could be achieved in areas that meet this criteria.

Figure 41 below illustrates the energy savings for a sample space for three different definitions of the daylit area for Title 24: a.) the blue line marks the boundary of energy savings from the current 2008 prescriptive "one head height" definition of the daylit area (graphical method), b.) the green line marks the energy savings achieved by a new simplified calculation method proposed for 2013's prescriptive approach (Watt Calc method) and c.) the orange line marks the cost-effective energy savings that could be achieved if all area at $sDA_{300,50\%}$ included photocontrols, or in other words, if a performance method were used for compliance that could calculate $sDA_{300,50\%}$. In Figure 41 the horizontal axis is the percent of area of the study space, a 60' wide x 40' deep open office with 26 percent net WWR (inside wall) at 70 percent VLT and no partitions around workstations. The vertical axis is the amount of time for which 300 lux is met or exceeded. The Blue line plots the achieved sDA: 10 percent sDA at 90 percent time, 20 percent sDA at 60 percent time. In this example $sDA_{300,50\%}$ = 23.75 percent.

Figure 41 : Energy Savings from Alternate Code Definitions of Daylit Area



If this code change proposal is successful, it will be adopted in 2013 and implemented in 2014, according to the current schedule. It is also conceivable that this approach would be taken further, using the $sDA_{300,50\%}$ metric to define a required daylit area in the CalGreen Reach Code and/or the next round of revision to Title 24 anticipated for 2017.

5.1.2 Glare Proxies

It is much less certain how the analysis of the various glare proxies may ultimately be applied to codes and standards. The metric which is closest to realization is the sun penetration metric, or MaxHrs, re-named "Annual Sun Exposure" (see discussion in Section 4.2.2). From this analysis, the regressions have shown that there are a maximum number of hours that a given sensor should potentially be in direct sunlight, such as no more than 300 hours for an "A' rating, or no more than 600 hours for a 'B' rating. However, the current challenge is that this metric applies only to a single point, and its impact on occupants within the defined study space, per the study sample a zone about 1300 square feet +/700 sf, for example within a range of no more than 30 or 40 feet.

It may be that further analysis will show that there are "sun exposure thresholds" in terms of hours above a given intensity, similar to the 300 lux and percent hours defined for sDA, that can be applied throughout the space, and then sun exposure can be reported at a percentage of area, as in "X percent of the area has less than Y hours of sun exposure, defined as more than 1000 lux of direct beam sunlight, assuming no blinds operation".

It would seem to be advantageous to have all of the daylight metrics resolve to criteria per square foot, or sensor point, so that they can be operated on in a unified equation. The IES DMC has resolved that an "Annual Sunlight Exposure" metric will be its immediate next priority to include with the report on spatial Daylight Autonomy.

5.2 Further Research

Perhaps the greatest need is for an extended effort to better understand the 'human factors' of daylighting. There is currently little information about human needs and preferences for daylit spaces, including the dynamic variance that is an integral quality of all daylit spaces.

5.2.1 Daylight Sufficiency

Laboratory studies testing the ranges found in the field study would be very useful. The field study suffered from numerous limitations, the most obvious being the loose relationship between the occupants and a specific daylighting condition, and likewise between the experts and an extended exposure to a range of conditions.

The current proposal for sDA describes annual exposure across an area. In the field study, it was not possible to pre-define "a daylit space" and limit occupant responses only to that area. Now that such a definition is available, more focused laboratory studies could establish study areas that meet a given criteria, such as 45 percent or 65 percent or 85 percent $sDA_{300,50\%}$ and then further gauge occupant acceptance of the daylighting conditions in those areas under a range of illumination conditions.

5.2.2 Blinds Operation

Better data on blinds operation, by orientation, space type, blinds type, pattern of sun penetration, interaction with view, and automated control operations is sorely needed to develop predictive models for simulation. Blinds operation has been shown by this field study to be a key factor in the determination of daylight availability. Blinds can also have an important impact on whole building energy use and occupant thermal comfort, two critical issues not addressed in this study. Blinds are also an essential element for allowing occupants to control their desire for view, balanced against highly individual preferences for privacy, security and visual comfort. Thus, the motivations for blinds operation are complex, and have important impacts on many building systems.

For the sake of moving forward with the analysis for this study, the project team made a set of simple but consistent assumptions about blinds operation. These were based on the best available information at the time, which unfortunately was limited to very small studies, personal experience, or previous simulation assumptions made with even less information.

The basic assumptions for this study were:

- Blinds would always be fully retracted, unless there was sun coming through the window
- For any hour with sunlight coming through the window, the blinds were deployed and set so that 20 percent of sunlight and skylight were transmitted (about a 60 percent angle for horizontal blinds), considering all possible inter-reflections. (For roller shades, the net transmittance was standardized at 5 percent)

It is understood, however, that the operation of blinds is far more variable than those simple assumptions. The controversy remains: should analysis be based on worst case assumptions? Best case assumptions? A statistical prediction of a population average?

In looking at monitored operation logs, Glen Hughes of the New York Times project reported that occupants will override automated controls to open their shades more frequently when they have a better view [Lee 2005, and personal communication from Glen Hughes]. In this field study 65 percent of occupants reported that their blinds were 75 percent to 100 percent open at the time of the survey, and that 22 percent reported sunlight patches within the room. Thus, there is evidence that occupant choices about blinds operation are strongly influenced by the quality of the view, and that some occupants may be more tolerant of sunlight penetration than is commonly assumed.

To date, it is not known how the type of blind system may influence occupant choices about operation. It is logical that the convenience of the blinds control will influence how actively the blinds are manually operated. But, is there a similar effect for overrides of automated blinds? Do "daylight optimized" blinds, for example those which preserve some daylight transmission and/or view preservation, result in different operation schedules? How much do other considerations, such as privacy or security or aesthetics, influence occupant choices about blinds operation?

5.2.3 BSFD Files

A major step forward achieved in this project was the creation of the dynamic Radiance approach that created the capability to use a matrix of BSDF files for simulation of dynamic blinds operation. Currently BSDF files can be generated from LBNL's Window 6 program from geometric descriptions of opaque slatted blinds. However, there are far more options available in the real world—specular, perforated or specially shaped metals, translucent fabric systems, optical films, dynamic transmission glass, and so forth—that need 3D descriptions of how light moves through them according to incident angle. Without those descriptions, their daylighting performance cannot be predicted by annual simulation programs, and thus manufacturers will have a difficult time proving the value of their products.

The BSDF format was developed for daylighting simulation programs such as Radiance. There remain many outstanding questions about preferred reporting and file formats for this data, such as how finally resolved it needs to be in space or spectra. There are also very limited (and expensive) testing facilities that can produce a BSDF result for a tested product.

There is a competing format for the 3D description of light transmission: the IES standard photometric files, which use polar plots for the description of light emitted form electric luminaires. This system is commonly used for simulation software developed for electric lighting. The light transmission of skylights was described in a time-sequence of photometric files via the PIER sponsored project [McHugh 2003]. Subsequently a number of skylight manufacturers have developed their own capability to generate photometric files for their skylights.

Given need for this information, and the expense of developing and maintaining testing facilities, it would seem that at a minimum a system to translate between the two formats should be established. Ideally, it would seem that one format could be selected that could serve the needs of both the daylighting and the electric lighting communities.

5.2.4 Glare Assessment

One of the glaring omissions in this study—pun intended—is the absence of simulated glare assessment of the study spaces and its interaction with daylight illuminance preferences. While glare is one of the most discussed concerns about daylighting, it remains one of the least understood and most poorly defined. Although subjective glare assessments were collected from the experts and occupants, the project team realized early in the project that they would not be able to use the simulations to generate universally recognized glare metrics for comparison to the subjective evaluations. This was for a variety of reasons:

- Glare metrics typically require luminance values, which are vastly more computationally intensive, than the illuminance values used in this project
- There are about a dozen competing glare metrics currently defined, each of which were developed independently to address certain conditions, and thus have their own strengths and preferred applications. A recent study by Robert Clear at LBNL [LBNL 2010] found little correlation in the predictions of the different metrics across comparable conditions.
- Glare metrics typically only apply to a single fixed point of view, rather than the entire space. Thus, any given space could have hundreds of glare assessments, depending upon the location and direction of view.
- Current glare metrics are not only dependent upon a fixed point of view, but also a fixed illumination condition, for example a single point in time. The project team is not aware any studies that attempt to understand the *dynamics* of glare under daylit conditions, such as the tolerable limits for frequency or duration of a glare condition, such as reflection off of water, or given a glare condition, what corrective actions occupants are likely to take (reorientation or location of task? closing blinds?)
- Compared to electric lighting conditions, most daylight generated glare conditions are dynamic and temporary—inter-reflections off of complex geometries of windows or blinds as the sun moves, temporary rain puddles or bright snow drift, reflections off of moving car windshields—and thus almost impossible to predict in terms of frequency.

Given these complexities in this study, the project team decided to try and find a metric generated from the simulation data that could predict the probability of glare. A variety of options were tested: various descriptions of the amount of sky visible from a space, interior illuminance intensity and uniformity, and various ways to describe the amount of sunlight entering a space. Only two—reducing the amount of direct sunlight that can make it into a space, and low annual daylight illuminance—resulted in useful predictions of occupant discomfort as gauged by Question F. And yet neither of these had very strong R^2 values, implying that there is considerable room for improvements to the specification of the metrics, and/or there are still other important factors yet to be added to the equation.

Overall, there is an urgent need for better understanding of how to predict and evaluate glare in daylit spaces.

5.2.5 Visual Comfort, Uniformity and View

Glare is the negative extreme on the scale of visual comfort. Lighting designers have long understood that there are other elements to visual comfort and satisfaction with the visual environment, such as uniformity of horizontal illumination, brightness of the vertical horizon, three dimensional rendering via sparkle and shadowing, color rendition and spectral content, and perhaps most importantly, the quality (and interest) of the view.

There was an attempt to summarize the impact of these other variables on occupant acceptance via the visual quality tables provided in the 9th addition of the IES Handbook. However, agreement on how to usefully quantify these attributes for an electrically lit environment has lagged, and even more so for daylit spaces.

Uniformity: As discussed above in Sections 3.3.2 and 4.2.2, daylighting professionals do not yet have a good method to describe illuminance uniformity in daylit spaces, especially under dynamic conditions. A foggy day is perhaps the ultimate in visual uniformity, while a small spot light outside at night at is the other extreme. What is the range for visual comfort in a daylit interior environment? And how can that acceptable range be described in space and time, and by task?

View quality: View quality is perhaps the greatest unknown in the visual quality equation, since both common sense and many research findings suggest that it is one of the greatest factors in occupant satisfaction with the visual environment. Indeed, in the PIER sponsored research [Heschong 2003] the quality of view predicted occupant satisfaction with every aspect of the interior environment. In other words, those occupants with the most interesting and/or largest views had the fewest complaints about lighting quality, noise levels, thermal comfort, and even health complaints such as fatigue or shoulder pain.

Unknowns about view include acceptable descriptions of effective angular size, brightness or contrast, distance, and most importantly, content. What content makes for an interesting view? Is it sky, vegetation, human activity, or any kind of dynamic variation? At what point does glare from large area contrast or small point sources overwhelm the advantages of content? Finally, can view quality be quantified so that it can be usefully factored into other visual quality equations?

5.3 Integration with other Organizations

There are many next steps to move the findings form this research out to a wider audience and more useful applications.

5.3.1 IES Publications

The IES DMC plans to start documenting an approved methodology for generating the adopted metrics, and suggested guidelines for establishing performance criteria based on those metrics. These documents are likely to include a Lighting Measurement (LM) document describing the detailed of the metrics and necessary methodology for generating them, followed by a Design Guideline (DG) discussing the three space types studied, and recommended criteria based on application needs.

Ultimately, the goal should be to integrate the recommended metrics into other IES documents, such as the Recommended Practice for Daylighting (RP-5) and the next edition of the IES Handbook (2014).

5.3.2 Software Capabilities

A key step in widespread use of the metrics is integration into software, both research grade and professional grade products, for example both publically and commercially funded. In support of this effort, software developers were invited to the 2010 Daylighting Forum, describe above, and a second symposium, just for software developers is planned to follow the 2011 LightFair in Philadelphia.

Integration with energy analysis software: The Dynamic Radiance approach, developed for this project, and successfully employed for both the Office Daylighting project [Saxena 2001] and the 2011 Title 24 Daylighting CASE report [CASE 2011], would greatly benefit from a graphic users' interface (GUI) and a users' manual. HMG has created the capability to automate input and output to larger energy simulation software, such as eQuest and EnergyPlus, to achieve more accurate predictions of daylight performance for whole building energy analysis. However, this automated process could and should be made available to other users via an internal capability in those programs.

Weather files: For commercial lighting software, the ability to use hourly weather files to generate daylight illuminance values is key to being able to generate the "climate-based" metric developed by this project. This process has been pioneered by Daysim and the Dynamic Radiance approach, via the use of segmented skies and daylight coefficients, and could be either imported into or integrated into commercial lighting design software.

Blinds operation: A second key need for commercial lighting design software is the ability to animate the operation of window coverings. Without dynamic operation of blinds or shades, annual daylight illumination metrics cannot be predicted.

5.3.3 IOU Efficiency Programs

Title 24 form the performance baseline for utility efficiency programs in California, so adoption of daylighting performance goals in Title 24 or CalGreen will help to establish the capability of new construction programs such as Savings by Design to require a minimum and incentivize better daylighting performance.

Retrofit: The Office Daylighting project, another component of this Daylighting Plus PIER program [Saxena 2011], utilized the sDA metric to establish savings estimates for retrofitting existing office buildings in California. Once the magnitude of potential savings are known, it will be easier to justify large programs aimed at capitalizing on and improving the daylighting potential of existing buildings around the state. Both retrofit and new construction programs are likely to increase the potential for demand reduction via advanced electric lighting systems, such as dimming ballasts, task/ambient lighting, and automated controls.

Net Zero: Finally, in the drive to Net Zero energy buildings, daylighting will play an important role in reducing daytime electric lighting use to minimum levels. Integrated with passive heating and cooling techniques [Heschong 2011c], daylighting can help reduce overall energy needs for buildings so that the remaining loads can be met with on-site and/or renewable generation systems.

5.3.4 Product Manufacturers' Associations

Another frontier for daylighting integration is into the performance evaluation of products. Successful daylighting has traditionally been considered a function of architectural design, utilizing spatial geometry, common materials of glass windows and plastic skylights, opaque walls and floors, and perhaps traditional window coverings like curtains or blinds. However, with the advent of spectrally selective and optically complex glazing, active solar tracking systems, daylight redirection devices, automated blinds and shades, and so forth., manufacturers need to be able to communicate the daylighting advantages of their products.

A number of manufacturers associations are increasingly interested in how to describe the performance of their products, such as long term advantages for visual quality and energy performance can be realized. NEMA has formed the Daylighting Council of the Lighting Controls Association and AAMA has long maintained a Skylighting Council.

More recently the National Fenestration Rating Council has begun to consider daylighting performance as part of its purview, in addition to the original rating of the thermal performance of fenestration products. Manufacturers involved in this organization include those who make glazing systems and films; window coverings, awnings, (grouped under "attachments"); and tubular daylighting devices. A presentation to the NFRC about the implications of this Daylighting Metrics project for their organization is included under a separate report on the Daylighting Plus Market Connections project [Heschong 2001b]. The recent formation of various committees to consider rating the daylighting performance of products,

CHAPTER 6: Glossary

BRE	British Building Research Establishment
CHPS	Coalition for High Performance Schools
DF	Daylight Factor
DMC	Daylight Metrics Committee
DSP	Daylight Saturation Percentage
DG	Design Guide
IES	Illuminating Engineering Society
IDL	Integrated Design Lab
IeCC	International Energy Construction Code
IgCC	International Green Construction Code
IOU	Investor Owned Utility
LBNL	Lawrence Berkeley National Laboratory
LEED	Leadership in Energy and Environmental Design
LM	Lighting Measurement
NFRC	National Fenestration Rating Council
NRC	National Research Council
NEEA	Northwest Energy Efficiency Alliance
SCE	Southern California Edison
USGBC	United States Green Building Council

CHAPTER 7: Bibliography

[Aiziewood 1993] M. E. Aiziewood. Innovative daylighting systems: An experimental evaluation. Lighting Research and Technology, 25(4): 141-152, 1 1993.

[Andersen 2001] M. Andersen, L. Michel, C. Roeker, and J. L. Scartezzini. Experimental assessment of bi-directional transmission distribution functions using digital imaging techniques. Energy and Buildings, 33(5): 417-431, 2001.

[Andersen 2005] M. Andersen, M. Rubin, R. Powles, and J. L. Scartezzini. Bi-directional transmission properties of venetian blinds: experimental assessment compared to ray-tracing calculations. Solar Energy, 78(2):187-198, 2005.

[Andersen 2008] M. Andersen, S. Kleindienst, L. Yi, J. Lee, M. Bodart, and B. Cutler. An intuitive daylighting performance analysis and optimization approach. Building Research & Information, 36(6): 593-607, 2008.

[ASHRAE 2008] ASHRAE Building Energy Labeling (ABEL) Ad-Hoc Committee. ASHRAE Building Energy Labeling Program: Promoting the Value of Energy Efficiency In the Real Estate Market. June 2008.

[Athienitis 2002] A. Athienitis and A. Tzempelikos. A Methodology for Simulation of Daylight Room Illuminance Distribution and Light Dimming for a Room With Controlled Shading Device. Solar Energy 72(4): 271-281, 2002.

[Bourgeois 2006] D. Bourgeois, C. F. Reinhart, and I. MacDonald. Adding advanced behavioural models in whole building energy simulation: A study on the total energy impact of manual and automated lighting control. Energy and Buildings, 38(7): 814-823, 2006.

[Bourgeois 2008] D. Bourgeois, C. F. Reinhart, and G. Ward. A Standard Daylight Coefficient Model for Dynamic Daylighting Simulations. Building Research & Information, 36(1): 68-82, 2008.

[Breitenbach 2001] J. Breitenbach, S. Lart, I. Langle, and J. L. J. Rosenfeld. Optical and thermal performance of glazing with integral venetian blinds. Energy and Buildings, 33(5):433-442, 2001.

[Carroll 2005] William L. Carroll and Robert J. Hitchcock. DELIGHT2 Daylighting Analysis in EnergyPlus: Integration and Preliminary User Results. IBPSA, 2005.

[Carter 2002] D.J. Carter. The measured and predicted performance of passive solar light pipe systems. Lighting Research and Technology, 34(1):39-51, 2002.

[CASE 2011] Codes and Standards Enhancement Initiative. California Utilities Statewide Codes and Standards Team. DRAFT Daylighting Report. Prepared by Heschong Mahone Group. March 24, 2011.

[CEC 2008] California Energy Commission. 2008 Building Energy Efficiency Standards for Residential and Nonresidential Buildings. 2008.

[CHPS 2006] The Collaborative for High Performance Schools. CHPS Best Practices Manual, Volume III – Criteria. Final Report. 2006.

[Christakou 2005] D. E. Christakou, and C. N. D. Amorim. Daylighting Simulation: Comparison of Softwares for Architect's Utilization. Building Simulation 2005: Ninth International IBPSA Conference, Montreal, Canada, August 15-18, 2005.

[Clear 2006] R. D. Clear, V. Inkarojrit, and E. S. Lee. Subject responses to electrochromic windows. Energy and Buildings, 38(7):758-779, 2006.

[Crisp 1978] V. H. C. Crisp. The light switch in buildings. Lighting Research and Technology, 10(2):69-82, 1 1978.

[DOE 1983] Building Systems Division of the U.S. Department of Energy. Daylighting Calculation in DOE-2. Prepared by Frederick C. Winkelmann, Building Energy Simulation Group, Energy and Environment Division, Lawrence Berkeley Laboratory. May 1983.

[Embrechts 1997] R Embrechts and C van Bellegem. Increased energy savings by individual light control. Right Light 4, Copenhagen, 1:179-182, 1997.

[Fernandes 2006] L. Fernandes, G. Ward, and E. S. Lee. Radiance-mathematical optimization of electrochromic operations for occupant comfort and non-energy provisions. Lawrence Berkeley National Laboratory. Paper LBNL-59821.

[Heschong 2003] Heschong Mahone Group. Windows and Offices: A Study of Office Worker Performance and the Indoor Environment. L. Heschong, Editor. CEC, California Energy Commission, 2003.

[Heschong 2006a] Heschong Mahone Group. Sidelighting photocontrols field study. Final Report to Southern California Edison Co, Pacific Gas & Electric Company and Northwest Energy Efficiency Alliance, 2006.

[Heschong 2006b] Heschong Mahone Group. Impacts of Standard Daylight Metrics on California Energy Use. Prepared for Pacific Gas and Electric Company, Emerging Technologies Program, Issued: January 3, 2006.

[Heschong 2010a] L. Heschong, M. Saxena, R. Higa. Improving Prediction of Daylighting Performance. ACEEE Summer Study on Energy Efficiency in Buildings, 2010.

[Heschong 2010b] Heschong Mahone Group. Daylighting Forum 2010 – Final Report. June 28, 2010. Available at: http://www.h-m-g.com/DaylightPlus/DaylightingForum2010Materials.htm

[Heschong 2011a] L. Heschong. Heschong Mahone Group. 2011. Daylight Metrics Project: Final Report. California Energy Commission. Publication Number: TBD

[Heschong 2011b] L. Heschong. Heschong Mahone Group. 2011. Market Connections Project: Final Report. California Energy Commission. Publication Number: TBD

[Heschong 2011c] Hechong Mahone Group. Very Low Energy Comfort Strategies – Phase 1 Report. Prepared for Southern California Edison. January 2011.

[Howlett 2007] O. Howlett, L. Heschong, J. McHugh. Scoping Study for Daylight Metrics from Luminance Maps. Leukos 3(3), January 2007.

[Hunt 1977] D. R. G. Hunt. Simple expressions for predicting energy savings from photo-electric control of lighting. Lighting Research and Technology, 9(2):93-102, 1 1977.

[Hunt 1979] D. R. G. Hunt. Improved daylight data for predicting energy savings from photoelectric controls. Lighting Research and Technology, 11(1):9-23, 3 1979.

[Hunt 1980] D. R. G. Hunt. Predicting artificial lighting use - a method based upon observed patterns of behaviour. Lighting Research and Technology,12(1):7-14, 1 1980.

[Jenkins 2005] David Jenkins, Tariq Muneer, and Jorge Kubie. A design tool for predicting the performances of light pipes. Energy and Buildings, 37(5):485-492, 2005.

[Kleindienst 2008] S. Kleindienst, M. Bodart, M. Andersen. Graphical Representation of Climate-Based Daylight Performance to Support Architectural Design. Leukos, 5(1): 39-61, 2008.

[Koti 2007] R. Koti and M. Addison. An Assessment of Aiding DOE-2's Simplified Daylighting Method With DAYSIM's Daylight Illuminances. Proceedings of the Solar Conference, American Solar Energy Society, Vol. 2: 726-733, 2007.

[Kuhn 2006] T. E. Kuhn. Solar control: A general evaluation method for facades with Venetian blinds or other control systems. Energy and Buildings 38(6): 661-672, 2006.

[Larson 1998] G. Ward Larson and R. Shakespeare. Rendering with Radiance: The Art and Science of Lighting Visualization. San Francisco: Morgan Kaufmann, 1998.

[LBNL 2010] Lawrence Berkeley National Laboratory. High Performance Building Façade Solutions Roundtable. Pacific Gas and Electric Company's Pacific Energy Center, April 20, 2010.

[Lee 2005] E. S. Lee, S. E. Selkowitz, G. D. Hughes, R. D. Clear, G. Ward, J. Mardaljevic, J. Lai, M. N. Inanici, and V. Inkarojrit. Daylighting the New York Times headquarters building. Lawrence Berkeley National Laboratory. Final report LBNL-57602, 2005.

[Loveland 2006] J. Loveland and K. Van Den Wymelenberg. Metrics for Daylighting Performance in Building Design. ACEEE Summer Study on Energy Efficiency in Buildings, 2006.

[Mardaljevic 1997] J. Mardaljevic. Validation of a lighting simulation program: a study using measured sky brightness distributions. Lux Europa 97 proc. 555-569, Amsterdam 1997.

[Mardaljevic 1998] J. Mardaljevic and K. Lomas. A simulation based method to evaluate the probability of daylight glare over long time periods and its application. CIBSE National Lighting Conference: 5-8 April, Lancaster University, UK, pages 282-291, 1998.

[Mardaljevic 2000a] J. Mardaljevic. The simulation of annual daylighting profiles for internal illuminance. Lighting Research and Technology, 32(3):111-118, 2000.

[Mardaljevic 2000b] J. Mardaljevic. Daylight Simulation: Validation, Sky Models and Daylight Coefficients. PhD thesis, De Montfort University, Leicester, UK, 2000.

[Mardaljevic 2006] J. Mardaljevic. Examples of climate-based daylight modeling. CIBSE National Conference 2006: Engineering the Future, 21-22 March, Oval Cricket Ground, London, UK, 2006.

[Mardaljevic 2008a] J. Mardaljevic. Climate-Based Daylight Analysis for Residential Buildings. Technical report, IESD, De Montfort University, Leicester Download from http://www.thedaylightsite.com/, 2008.

[Mardaljevic 2008b] J. Mardaljevic. Conclusion to CIE Reportership R3-26: Climate-Based Daylight Analysis. http://www.cie.co.at/div3/docs/mardaljevic-cie-rs.pdf, 2008.

[Mardaljevic 2009] J. Mardaljevic, L. Heschong, E. Lee. Daylight Metrics and Energy Savings. Lighting Research and Technology, 41(3): 261-283, 2009.

[McHugh 2003] J. McHugh. Heschong Mahone Group. 2003. Photometric Files: Technical Report. California Energy Commission. Publication Number: 500-03-083-A-15.

[Nabil 2005] A. Nabil and J. Mardaljevic. Useful daylight illuminance: a new paradigm for assessing daylight in buildings. Lighting Research & Technology, 37(1): 41-59, 2005.

[Nabil 2006] A. Nabil and J. Mardaljevic. Useful daylight illuminances: A replacement for daylight factors. Energy and Buildings, 38(7):905-913, 2006.

[Osterhaus 2005] W. K. E. Osterhaus. Discomfort glare assessment and prevention for daylight applications in office environments. Solar Energy, 79(2):140-158, 2005.

[Pande 2011] A. Pande, L. Heschong, D. Douglass. Heschong Mahone Group. 2011. Retail Revisioning Project: Final Report. California Energy Commission. Publication Number: TBD

[Pechacek 2008] C. S. Pechacek, M. Andersen and S. W. Lockley. Preliminary Method for Prospective Analysis of (Day)Light with Applications to Healthcare Architecture. Leukos, 5(1): 1-26, July 2008.

[Perez 1993] R. Perez, R. Seals, and J. Michalsky. All-weather model for sky luminance distribution – preliminary configuration and validation. Solar Energy, 50(3):235-245, 1993.

[Reinhart 2000] Christoph F. Reinhart and Sebastian Herkel. The simulation of annual daylight illuminance distributions – a state-of-the-art comparison of six radiance-based methods. Energy and Buildings, 32(2):167-187, 2000.

[Reinhart 2001] Christoph F. Reinhart and Oliver Walkenhorst. Validation of dynamic radiance-based daylight simulations for a test office with external blinds. Energy and Buildings, 33(7):683-697, 2001.

[Reinhart 2004a] Christoph F. Reinhart. Lightswitch-2002: a model for manual and automated control of electric lighting and blinds. Solar Energy, 77(1): 15-28, 2004.

[Reinhart 2004b] C. Reinhart and C. Jones. Electric Lighting Energy Savings for On/Off Photocell Control – A Comparative Simulation Study for Using DOE2.1 and Daysim. esim proc., Vancouver, Canada, June 9-11, 2004

[Reinhart 2005] Christoph F. Reinhart. A Simulation-Based Review of the Ubiquitous Window-Head-Height to Daylit Zone Depth Rule-of-Thumb. Proceedings of Building Simulation 2005, Montreal, Canada, August 2005.

[Reinhart 2006a] C. F. Reinhart, J. Mardaljevic, and Z. Rogers. Dynamic daylight performance metrics for sustainable building design. Leukos, 3(1), 2006.

[Reinhart 2006b] Christoph F. Reinhart and Marilyne Andersen. Development and validation of a Radiance model for a translucent panel. Energy and Buildings, 38(7):890-904, 2006.

[Roche 2000] L Roche, E. Dewey, and P. Littlefair. Occupant reaction to daylight in offices. Lighting Research and Technology, 32(3), 2000.

[Roche 2002] L Roche. Summertime performance of an automated lighting and blinds control system. Lighting Research and Technology, 34(1): 11-25, 2002.

[Saxena 2010] M. Saxena, L. Heschong, K. Van Den Wymelenberg, S. Wayland. 61 Flavors of Daylight. ACEEE Summer Study on Energy Efficiency in Buildings, 2010.

[Saxena 2011] M. Saxena, and L. Heschong. Heschong Mahone Group. 2011. Office Daylight Project: Final Report. California Energy Commission. Publication Number: TBD

[Shahid 2005] H. Shahid, D. Naylor. Energy performance assessment of a window with a horizontal Venetian blind. Energy and Buildings 37: 836-843, 2005.

[Tregenza 1983] P. R. Tregenza and I. M.Waters. Daylight coefficients. Lighting Research and Technology, 15(2):65-71, 1 1983.

[Tsangrassoulis 2006] A. Tsangrassoulis, V. Bourdakis, V. Geros, M. Santamouris. A genetic algorithm solution to the design of slat-type shading system. Renewable Energy 31: 2321-2328, 2006.

[Tzempelikos 2007] A. Tzempelikos, A. Athienitis, P. Karava. Simulation of façade and envelope design options for a new institutional building. Solar Energy 81(9): 1088-1103, 2007.

[Tzempelikos 2008] A. Tzempelikos. The impact of venetian blind geometry and tilt angle on view, direct light transmission and interior illuminance. Solar Energy 82(12): 1172-1191, 2008.

[USGBC 2005] The U.S. Green Building Council. LEED: Leadership in Energy and Environmental Design, 2005.

[Vine 1998] E. Vine, E. S. Lee, R. Clear, D. DiBartolomeo, and S. Selkowitz. Office workers response to an automated venetian blind and electric lighting system - a pilot study. Energy and Buildings, 28(2), 1998.

[Webb 2006] A. R. Webb. Considerations for lighting in the built environment: Non-visual effects of light. Energy and Buildings, 38(7): 721-727, 2006.

[Weinold 2006] Jan Wienold and Jens Christoffersen. Evaluation methods and development of a new glare prediction model for daylight environments with the use of ccd cameras. Energy and Buildings, 38(7):743-757, 2006.

[Wienold 2007] Jan Wienold. Dynamic simulation of blind control strategies for visual comfort and energy balance analysis. IBPSA, pages 1197-1204, 2007.

APPENDIX A:
Survey Forms

A-1 Occupant Survey

Bldg ID_______ Room ID_______ Survey ID_______

OCCUPANT SURVEY – How Comfortable is this Room?

1. Today's date _____day______month______year 2. Your age:____________yrs.

Please choose the closest correct answer

3. What are the weather conditions right now?
❑ Its a foggy day
❑ It's a lightly overcast day
❑ Its a dark overcast day (and/or rain or snow)
❑ I can see patches of sunlight inside this room
❑ I can see patches of sunlight, but only outside of this room
❑ It's a clear blue day, but I can't see any direct sunlight
❑ It is variable, with big clouds moving by and occasional sun

4. About how close are you to a window with a view?
❑ about 5 feet from the window ❑ 10-15 feet from the window ❑ 20-30 feet (or more) from the window
❑ I can't see any view from where I work ❑ not applicable or don't know

5. If this room has windows with blinds or curtains, overall right now are they:
❑ fully closed ❑ ¾ closed ❑ ½ closed ❑ ¼ closed ❑ fully open ❑ no blinds or curtains

6. For about how long have you been using this room?
❑ just today ❑ a week ❑ a month ❑ 2-4 months ❑ 5-11 months ❑ a year or more

7. When you come here, how many hours per day to you generally spend in this space?
❑ an hour or less ❑ 2-4 hours ❑ 5-7 hours ❑ 8 or more hours per day

Please consider your experience of this room based on ALL the time you have spent here.

	Worse << >> Better
8. I enjoy being in this room	Strongly Disagree 1 2 3 4 5 6 7 8 9 Strongly Agree n/a
9. I find this room visually attractive	Strongly Disagree 1 2 3 4 5 6 7 8 9 Strongly Agree n/a
10. Temperature in the room is always comfortable	Strongly Disagree 1 2 3 4 5 6 7 8 9 Strongly Agree n/a
11. Noise level in the room is always comfortable	Strongly Disagree 1 2 3 4 5 6 7 8 9 Strongly Agree n/a
12. I like the view I have from the window	Strongly Disagree 1 2 3 4 5 6 7 8 9 Strongly Agree n/a
13. I think the view out the window(s) is big enough	Strongly Disagree 1 2 3 4 5 6 7 8 9 Strongly Agree n/a
14. I am happy with how the blinds (or curtains) operate	Strongly Disagree 1 2 3 4 5 6 7 8 9 Strongly Agree n/a
15. The lighting conditions are always comfortable	Strongly Disagree 1 2 3 4 5 6 7 8 9 Strongly Agree n/a
16. The electric light in this room is always sufficient	Strongly Disagree 1 2 3 4 5 6 7 8 9 Strongly Agree n/a
17. The electric lights are never too bright	Strongly Disagree 1 2 3 4 5 6 7 8 9 Strongly Agree n/a
18. I can work happily in this room with SOME of the electric lights turned off	Strongly Disagree 1 2 3 4 5 6 7 8 9 Strongly Agree n/a
19. I can work happily in this room with ALL of the electric lights turned off (using only daylight)	Strongly Disagree 1 2 3 4 5 6 7 8 9 Strongly Agree n/a
20. The daylight in this room is always sufficient	Strongly Disagree 1 2 3 4 5 6 7 8 9 Strongly Agree n/a
21. The daylight in this room never is too bright	Strongly Disagree 1 2 3 4 5 6 7 8 9 Strongly Agree n/a
22. I am able to do my work here without any problems from glare or troubling reflections	Strongly Disagree 1 2 3 4 5 6 7 8 9 Strongly Agree n/a

(See over for optional comments…)

This survey is part of a study funded by Public Interest Energy Research (PIER) through the California Energy Commission (CEC) and others. The results of this survey will be used to guide the development of better buildings. Your responses will remain anonymous. If you have any questions about the survey, please contact Mudit Saxena at Heschong Mahone Group. (916) 962-7001

OPTIONAL QUESTIONS:

23. What do you like most about the visual conditions in this room?

24. What do you like least about the visual conditions in this room?

25. If you could make any changes, how would you improve the visual conditions in this room?

26. Any other comments?

Thank you!
Please return this survey to the person who gave it to you.

This survey is part of a study funded by Public Interest Energy Research (PIER) through the California Energy Commission (CEC, the Northwest Energy Efficiency Alliance and the New York State Research and Development Authority. The results of this survey will be used to guide the development of better buildings. Your responses will remain anonymous. If you have any questions about the survey, please contact Mudit Saxena at Heschong Mahone Group. at (916) 962-7001 or Saxena@h-m-g.com

All surveys should be returned to
Daylighting Surveys
Heschong Mahone Group
11626 Fair Oaks Blvd #320
Fair Oaks, California, 95628

A-2 Expert Survey

EXPERT SURVEY – Daylighting Metrics Study, Space Evaluation

Your Name: ______________________________

Building Name: ______________ City: ______________

Space #: ______________ Space Description: ______________

Date: ______________ Time: ______________

Locate yourself in two to six normal work position(s) within the study space, and consider how you would answer these questions if you were an occupant, based on your experience, and relative to projected ***annual*** *weather conditions. The 1-9 scale can be interpreted as a percent probability of the condition occurring. Ratings should integrate all representative positions.*

The blinds and electric lights in the space should be evaluated as found (or if the space is unoccupied, under expected normal operating conditions).		Worse <<							>> Better		
		1	2	3	4	5	6	7	8	9	n/a
1. I enjoy being in this room.	Strongly Disagree	☐	☐	☐	☐	☐	☐	☐	☐	☐ Strongly Agree	☐
2. I find this room visually attractive.	Strongly Disagree	☐	☐	☐	☐	☐	☐	☐	☐	☐ Strongly Agree	☐
3. Temperature in the room is always comfortable.	Strongly Disagree	☐	☐	☐	☐	☐	☐	☐	☐	☐ Strongly Agree	☐
4. Noise levels in the room always comfortable.	Strongly Disagree	☐	☐	☐	☐	☐	☐	☐	☐	☐ Strongly Agree	☐
5. I like the view I have from the window.	Strongly Disagree	☐	☐	☐	☐	☐	☐	☐	☐	☐ Strongly Agree	☐
6. I think the view out the window(s) is big enough.	Strongly Disagree	☐	☐	☐	☐	☐	☐	☐	☐	☐ Strongly Agree	☐
7. I am happy with how the blinds (or curtains) can be operated.	Strongly Disagree	☐	☐	☐	☐	☐	☐	☐	☐	☐ Strongly Agree	☐
8. The lighting conditions are always comfortable.	Strongly Disagree	☐	☐	☐	☐	☐	☐	☐	☐	☐ Strongly Agree	☐
9. The electric light in this room is always sufficient.	Strongly Disagree	☐	☐	☐	☐	☐	☐	☐	☐	☐ Strongly Agree	☐
10. The electric lights are never too bright (i.e. not causing visual discomfort or glare)	Strongly Disagree	☐	☐	☐	☐	☐	☐	☐	☐	☐ Strongly Agree	☐
11. I can work happily in this room with SOME of the electric lights turned off.	Strongly Disagree	☐	☐	☐	☐	☐	☐	☐	☐	☐ Strongly Agree	☐
12. I can work happily in this room with ALL of the electric lights turned off (using only daylight).	Strongly Disagree	☐	☐	☐	☐	☐	☐	☐	☐	☐ Strongly Agree	☐
13. The daylight in this room is always sufficient.	Strongly Disagree	☐	☐	☐	☐	☐	☐	☐	☐	☐ Strongly Agree	☐
14. The daylight in this room is never too bright (i.e. not causing visual discomfort or glare).	Strongly Disagree	☐	☐	☐	☐	☐	☐	☐	☐	☐ Strongly Agree	☐
15. I am able to do my work here without any problems from glare or troubling reflections.	Strongly Disagree	☐	☐	☐	☐	☐	☐	☐	☐	☐ Strongly Agree	☐

Name: *Bldg:* *Space ID:*

Detailed Assessment (Electric lights OFF, if possible)

16. Lights: ☐ AS FOUND ☐ ALL OFF ☐ _____% off

17. Window Covers ☐ AS FOUND ☐ OPENED FOR STUDY

*Rate this room under **today's** conditions for:*

Blinds and/or curtains left as found upon entering room, unless the room is unoccupied and they are completely closed, in which case, open them.	Worse <<	1	2	3	4	5	6	7	8	9	>> Better	n/a
18. Daylight uniformity	Very unpleasant	☐	☐	☐	☐	☐	☐	☐	☐	☐	Very pleasant	☐
19. Vertical surface brightness	Very unpleasant	☐	☐	☐	☐	☐	☐	☐	☐	☐	Very pleasant	☐
20. Highlights / Visual Interest (please include whole scene & view outside)	Very unpleasant	☐	☐	☐	☐	☐	☐	☐	☐	☐	Very pleasant	☐
21. Quality of view to the outside	Non-existent	☐	☐	☐	☐	☐	☐	☐	☐	☐	Excellent	☐
22. Legibility of computer or other display screens	Illegible	☐	☐	☐	☐	☐	☐	☐	☐	☐	Highly Legible	☐
23. Legibility of signage/display/teaching media	Illegible	☐	☐	☐	☐	☐	☐	☐	☐	☐	Highly Legible	☐
24. Legibility of faces in all directions	Illegible	☐	☐	☐	☐	☐	☐	☐	☐	☐	Highly Legible	☐
25. Legibility of fine newsprint on a desk	Illegible	☐	☐	☐	☐	☐	☐	☐	☐	☐	Highly Legible	☐
26. Legibility of glossy magazine on a desk	Illegible	☐	☐	☐	☐	☐	☐	☐	☐	☐	Highly Legible	☐

*The follow assessments should be based on your best guess of **annual** conditions:*

		1	2	3	4	5	6	7	8	9		n/a
27. Ability of occupants to control visual conditions to maintain their personal comfort	Non-existent	☐	☐	☐	☐	☐	☐	☐	☐	☐	Excellent	☐
28. Probability of direct glare from daylight aperture	Too Much Glare	☐	☐	☐	☐	☐	☐	☐	☐	☐	No Glare	☐
29. Probability of direct glare from sun penetration	Too Much Glare	☐	☐	☐	☐	☐	☐	☐	☐	☐	No Glare	☐
30. Probability of veiling glare on computer screens from daylight	Too Much Glare	☐	☐	☐	☐	☐	☐	☐	☐	☐	No Glare	☐
31. Probability of veiling glare on whiteboards or wall displays from daylight	Too Much Glare	☐	☐	☐	☐	☐	☐	☐	☐	☐	No Glare	☐
32. Probability that some occupants will overheat from excessive daylight or sunlight	Serious discomfort	☐	☐	☐	☐	☐	☐	☐	☐	☐	Never	☐
33. Probability that some occupants will be chilled when near windows or skylights	Serious discomfort	☐	☐	☐	☐	☐	☐	☐	☐	☐	Never	☐
34. Acoustic privacy in space	Non existent	☐	☐	☐	☐	☐	☐	☐	☐	☐	Excellent	☐
35. Acoustic isolation from the outside noise	Non existent	☐	☐	☐	☐	☐	☐	☐	☐	☐	Excellent	☐

Name : Bldg: Space ID:

Temporal Estimation of Daylight in Space

Consider all influences on daylight, including external obstructions, changes in vegetation and ground cover, and changing sun angles. Rate the day for ALL occupied hours, and your best guess for how the occupants will operate the blinds or other fenestration control devices. Assume a "theoretically perfect" electric lighting design and control system that would produce illumination conditions acceptable to you. The savings percentage is a combination of both time and space, or "full load savings equivalent" for the electric lighting system.

You can use the 1-9 scale as a proxy for percent of lights off. So, for example, 9 = the electric lights could be turned of 90% of the time (90% full load hours savings), 5 = 50% of the lights could be turned off all day, or 100% the lights could be turned off for half the day, and 1 = 10% reduction in lighting energy use. (consider illumination output, not power)

	Worse << >> Better											
Over the course of a day, do you think there will be sufficient daylight illumination in this space, for:												
		1	2	3	4	5	6	7	8	9		n/a
36. **Today's** weather conditions	Insufficient Daylight	☐	☐	☐	☐	☐	☐	☐	☐	☐	Sufficient Daylight	☐
37. A **summer** (light) overcast day	Insufficient Daylight	☐	☐	☐	☐	☐	☐	☐	☐	☐	Sufficient Daylight	☐
38. A **winter** (heavy) overcast day	Insufficient Daylight	☐	☐	☐	☐	☐	☐	☐	☐	☐	Sufficient Daylight	☐
39. A sunny **summer** day	Insufficient Daylight	☐	☐	☐	☐	☐	☐	☐	☐	☐	Sufficient Daylight	☐
40. A sunny **spring** day	Insufficient Daylight	☐	☐	☐	☐	☐	☐	☐	☐	☐	Sufficient Daylight	☐
41. A sunny **fall** day	Insufficient Daylight	☐	☐	☐	☐	☐	☐	☐	☐	☐	Sufficient Daylight	☐
42. A sunny **winter** day	Insufficient Daylight	☐	☐	☐	☐	☐	☐	☐	☐	☐	Sufficient Daylight	☐
Over the course of a day, do you think there will be glare or sun penetration problems in this space?												
		1	2	3	4	5	6	7	8	9		n/a
43. **Today's** weather conditions	Serious Problem	☐	☐	☐	☐	☐	☐	☐	☐	☐	No Problem	☐
44. A **summer** (light) overcast day	Serious Problem	☐	☐	☐	☐	☐	☐	☐	☐	☐	No Problem	☐
45. A **winter** (heavy) overcast day	Serious Problem	☐	☐	☐	☐	☐	☐	☐	☐	☐	No Problem	☐
46. A sunny **spring** day	Serious Problem	☐	☐	☐	☐	☐	☐	☐	☐	☐	No Problem	☐
47. A sunny **summer** day	Serious Problem	☐	☐	☐	☐	☐	☐	☐	☐	☐	No Problem	☐
48. A sunny **fall** day	Serious Problem	☐	☐	☐	☐	☐	☐	☐	☐	☐	No Problem	☐
49. A sunny **winter** day	Serious Problem	☐	☐	☐	☐	☐	☐	☐	☐	☐	No Problem	☐

Name : *Bldg:* *Space ID:*

Descriptive Questions

50. Describe the key sources of visual discomfort in the space.

51. Describe the best daylighting feature(s) in the space

52. Describe the worst daylighting feature(s) in the space

53. How would you suggest the space's daylighting could best be improved?

54. Other comments:

If you not part of group workshop with surveyor concurrently documenting conditions, then please --

note today's weather conditions: ____________________

note position of blinds: ____________________

room unoccupied or # of occupants present: ____________________

A-3 Building Survey

Date: 11-30-2007 Bldg Name: Surveyor Initials: DB/GG

Host Name: Phone:

BUILDING ADDRESS AND MAP VIEWS

ADDRESS:

INSTRUCTIONS TO SURVEYORS

- Definition of the space is:

- Since there are many shelves in the study space, take one reflectance reading for each shelf that is part of the study space (middle of shelf).

- For the shelves in the "extra" space, take a few (3-4) sample reflectance readings.'

- There are wooden beams on the roof of space 1. Show those on the plan, show spacing distance bet. them. Get a reflectance reading (of something comparable in color to them that you can easily reach).

- Height and dist. of trees seen from the window in the 1st space are important. Tell us what type of trees they are. Ask the librarian if unknown.

- Show us location of all the lights fixtures and how they are switched.

- There is a lot of "extra space" in space1. We can draw the basic geometry from plan, but will need reflectances for various surfaces. Try and get as many as you can. Rest we will take as defaults.

Date: 11-30-2007 Bldg Name: Surveyor Initials: DB/GG

Host Name: Phone:

Outside Readings

Take spot readings with a hand-held illuminance meter. One set before the start of the space surveys and one set after the end of the space surveys.

SET 1 (Survey Start)		**SET 2 (Survey End)**	
Time: 8:00 AM		Time: 2:40 PM	
Direct Sun: 875 fc	Shade: 540 fc	Direct Sun: 640 fc	Shade: 570 fc
Describe sky condition: Partial Cloud / Clear		Describe sky condition: Overcast	

Height of Space above Ground

Note if space is located at ground level. If not, what floor and height of typical floor in building.

SPACE 1

Floor Number: Ground Level **AND** Typical Floor-Floor Height: 26 ft **OR** Height from Ground: 0 ft

SPACE 2

Floor Number: First Floor **AND** Typical Floor-Floor Height: 11'4" **OR** Height from Ground: 14'8"

Photograph List

Description	Photo #	Description	Photo #
☒ -1: Photo of Building sign		☒ -2-5: Photos of Window Details **(Space 2 – N/A)**	
☒ -1: Photo of sky condition (Survey Start)		☒ -2-5: Photos of Clerestory Details **(Space 1 – N/A)**	
☒ -2-5: Photos of Windows Wall showing blind positions **(w/Flash)** **(Space 1 – N/A)**		☒ -2-5: Photos of Furniture (> 4')	
☒ -2-5: Photos of Clerestory **(w/Flash)** **(Space 1 – N/A)**		☒ -2-4: Photos of Exterior Façade with Study Space	
☒ -2-5: Photos of view outside windows (looking straight to horizon)		☒ -2-5: Photos of Exterior Obstructions	
☒ -2-5: Elevational Photos of Interior Walls **(w/Flash)**		☒ -2-5: Photos of landscape	
☒ -1-4: Close-up of Blinds **(w/Flash)** **(Space 1 – N/A)**		☒ -1: Photo of sky condition (Survey End)	
		☐ -__________	

Date: 11-30-2007 Bldg Name: Surveyor Initials: DB/GG

Host Name: Phone:

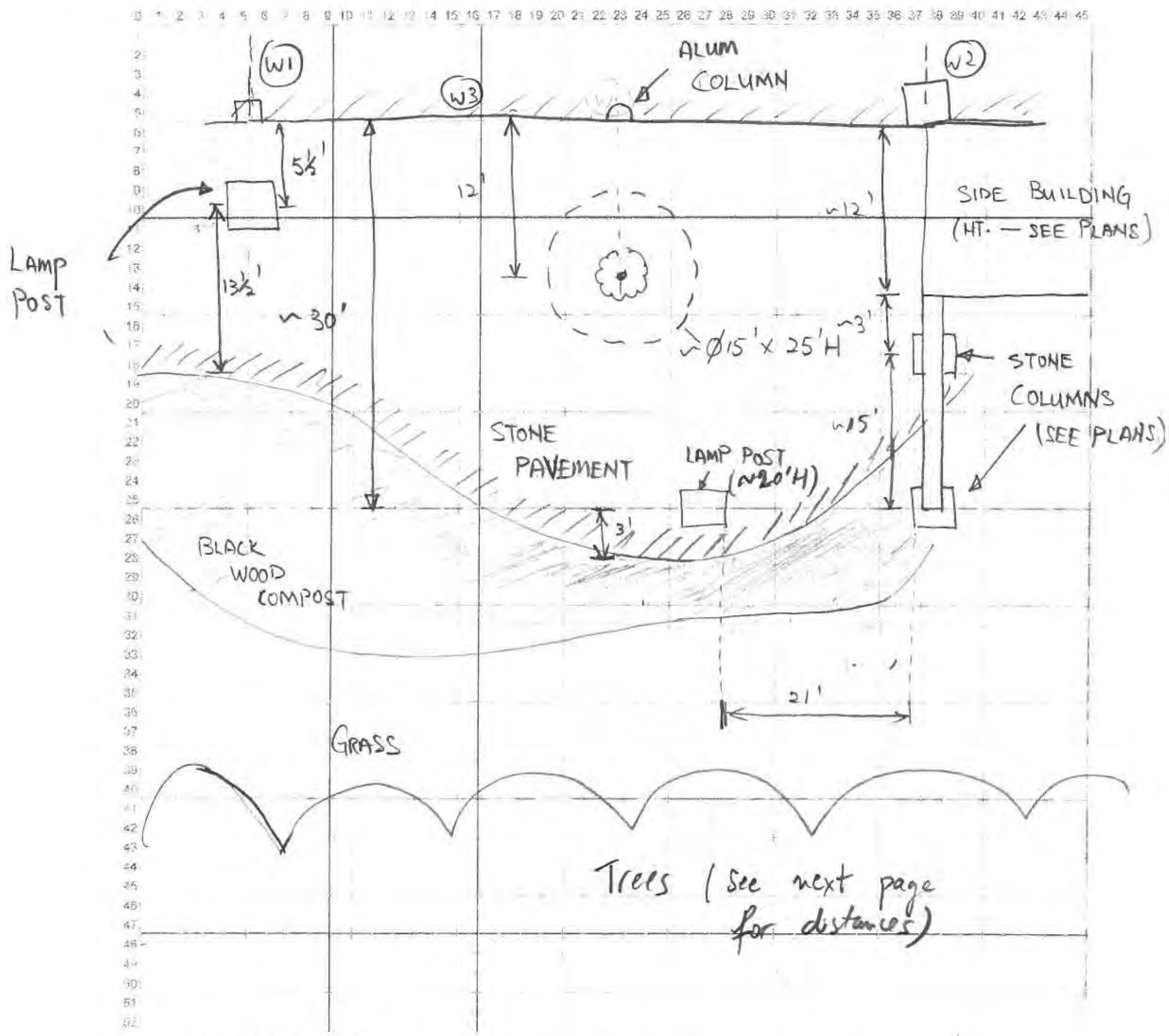
SURVEY EQUIPMENT LIST

- ☐ *Satellite photos of site plan, 3D view of space and 3D view of surrounding obstructions*
- ☐ *Survey Forms including internal elevation photographs*
- ☐ *HB Pencil, Black and Red Pen*
- ☐ *Laser Rangefinder (Indoor measurements)*
- ☐ *Laser Rangefinder (Outdoor measurements)*
- ☐ *Measuring Tape*
- ☐ *Illuminance Meter handheld*
- ☐ *Reference Surface (gray card)*
- ☐ *Compass showing magnetic North*
- ☐ *Protractor or angle measuring device*
- ☐ *Digital Camera*
- ☐ *Foot Scale*

Date:________________Bldg Name:________________________________Surveyor Initials:____________

Host Name:____ Phone:________________

EXTERIOR OBSTRUCTION DETAILS *(OPTIONAL)*



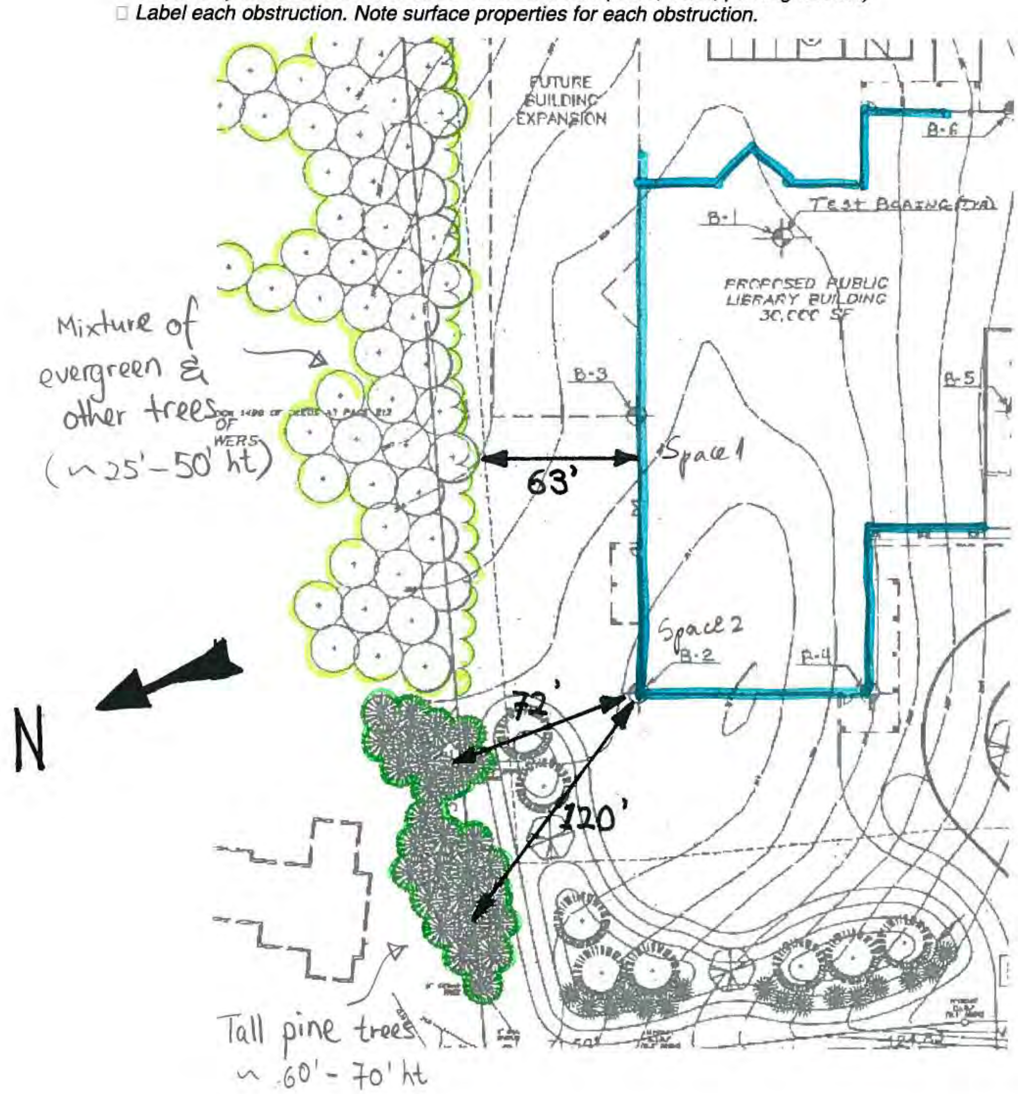
☐ *Show MAGNETIC NORTH arrow*
☐ *Sketch key external elements close to the windows (walls, trees, parking lots etc)*
☐ *Label each obstruction. Note surface properties for each obstruction.*

Date: 11-30-2007 Bldg Name: Surveyor Initials: DB/GG

Host Name: Phone:

EXTERIOR OBSTRUCTION DETAILS *(OPTIONAL)*

- ☐ *Show MAGNETIC NORTH arrow*
- ☐ *Sketch key external elements close to the windows (walls, trees, parking lots etc)*
- ☐ *Label each obstruction. Note surface properties for each obstruction.*



A-4 Space Survey

Date: 11-30-2007 ______ Bldg Name: Surveyor Initials: DB/GG ______

Host Name: ________________ Phone:

INSTRUCTIONS TO SURVEYORS

Definition of the space is:

- Since there are many shelves in the study space, take one reflectance reading for each shelf that is part of the study space (middle of shelf).

- For the shelves in the "extra" space, take a few (3-4) sample reflectance readings.'

- There are wooden beams on the roof of space 1. Show those on the plan, show spacing distance bet. them. Get a reflectance reading (of something comparable in color to them that you can easily reach).

- Height and dist. of trees seen from the window in the 1st space are important. Tell us what type of trees they are. Ask the librarian if unknown.

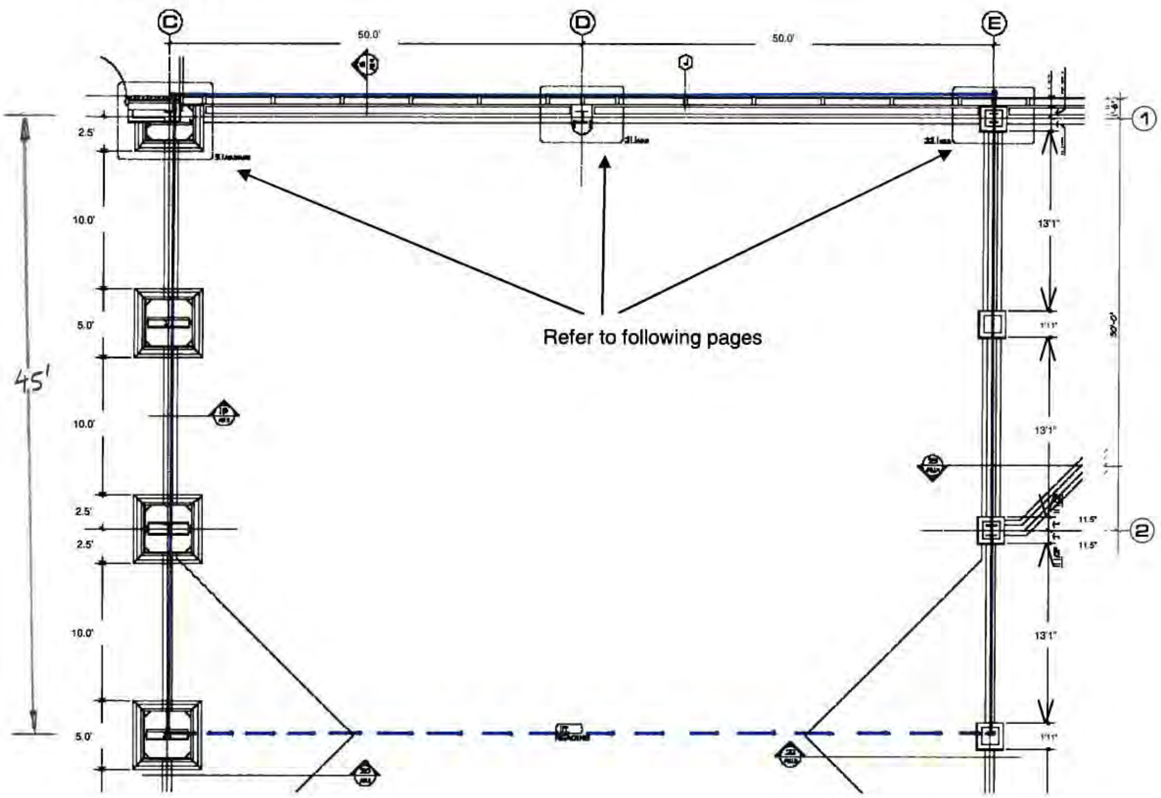
- Show us location of all the lights fixtures and how they are switched.

- There is a lot of "extra space" in space1. We can draw the basic geometry from plan, but will need reflectances for various surfaces. Try and get as many as you can. Rest we will take as defaults.

Date: 11-30-2007 Bldg Name: Surveyor Initials: DB/GG

Host Name: Phone:

SPACE PLAN



- Sketch plan of study space with partitions & furniture.
- Show MAGNETIC NORTH arrow
- Mark Wall 1 as wall with entrance to space (may be an air wall), Wall 2, 3, and 4 are marked clock wise
- Highlight exterior walls by filling in the walls. Internal walls and partitions by double line outline only.
- Note all windows (WI), clerestories (CL) and skylights (SK). Note Type of each.
- Provide dimensions for all walls, windows, partitions and furniture **in Black**
- Mark Reflectances for all surfaces seen in plan view **in Red**

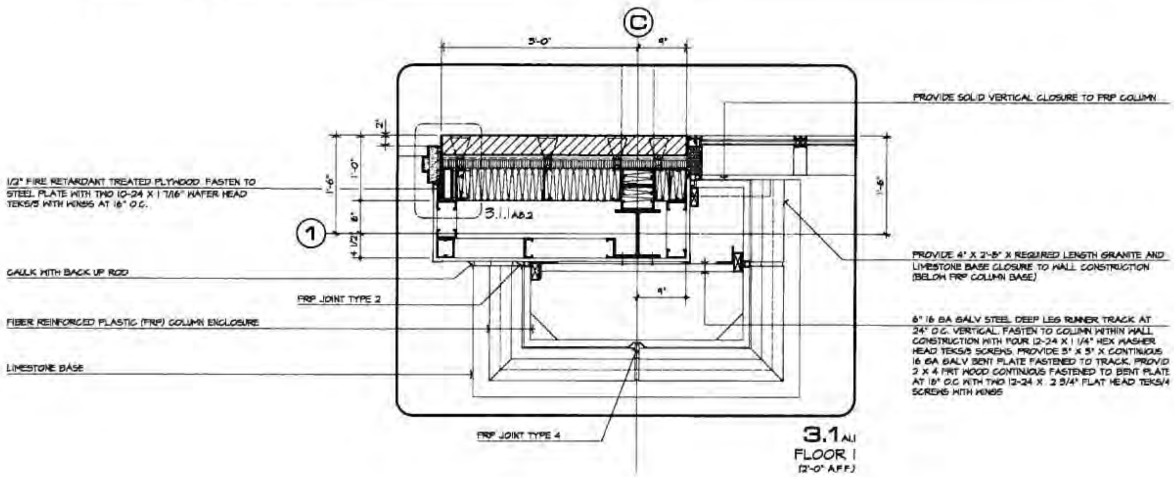
W1

WI-1 SK-1 CL-1

Date: 11-30-2007 Bldg Name: _ Surveyor Initials: DB/GG

Host Name: _______________ Phone: _______

SPACE PLAN

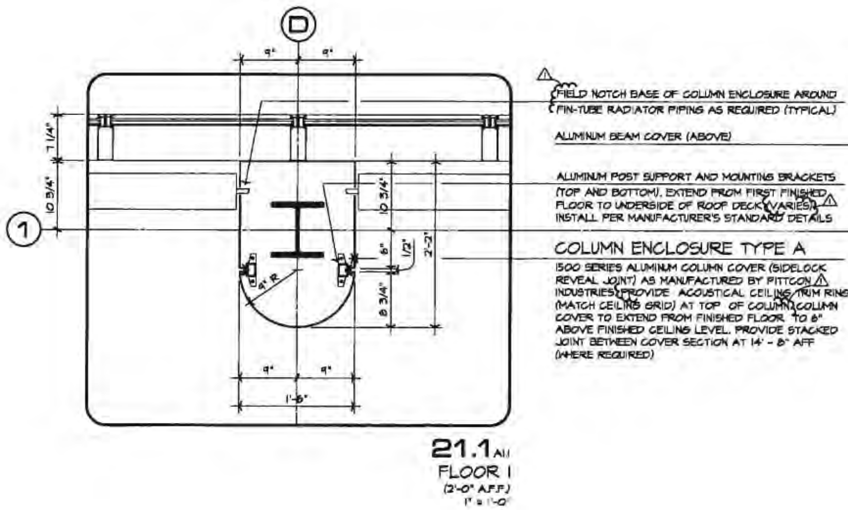


- ☐ *Sketch plan of study space with partitions & furniture.*
- ☐ *Show MAGNETIC NORTH arrow*
- ☐ *Mark Wall 1 as wall with entrance to space (may be an air wall), Wall 2, 3, and 4 are marked clock wise*
- ☐ *Highlight exterior walls by filling in the walls. Internal walls and partitions by double line outline only.*
- ☐ *Note all windows (WI), clerestories (CL) and skylights (SK). Note Type of each.*
- ☐ *Provide dimensions for all walls, windows, partitions and furniture **in Black***
- ☐ *Mark Reflectances for all surfaces seen in plan view **in Red***

Date: 11-30-2007 Bldg Name: Surveyor Initials: DB/GG

Host Name: Phone:

SPACE PLAN

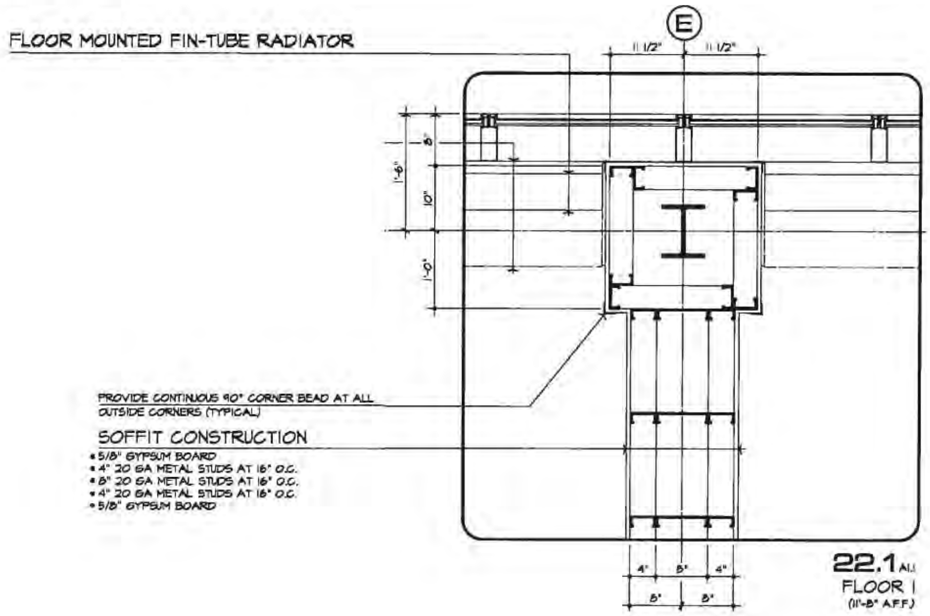


- ☐ *Sketch plan of study space with partitions & furniture.*
- ☐ *Show MAGNETIC NORTH arrow*
- ☐ *Mark Wall 1 as wall with entrance to space (may be an air wall), Wall 2, 3, and 4 are marked clock wise*
- ☐ *Highlight exterior walls by filling in the walls. Internal walls and partitions by double line outline only.*
- ☐ *Note all windows (WI), clerestories (CL) and skylights (SK). Note Type of each.*
- ☐ *Provide dimensions for all walls, windows, partitions and furniture* ***in Black***
- ☐ *Mark Reflectances for all surfaces seen in plan view* ***in Red***

Date: 11-30-2007 Bldg Name: Surveyor Initials: DB/GG

Host Name: Phone:

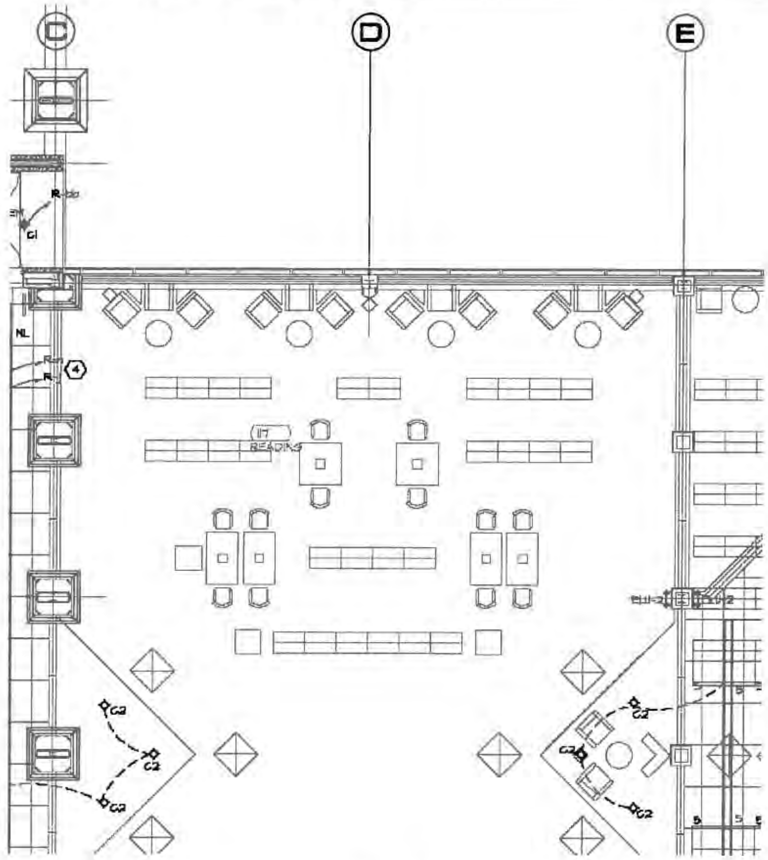
SPACE PLAN



- ☐ *Sketch plan of study space with partitions & furniture.*
- ☐ *Show MAGNETIC NORTH arrow*
- ☐ *Mark Wall 1 as wall with entrance to space (may be an air wall), Wall 2, 3, and 4 are marked clock wise*
- ☐ *Highlight exterior walls by filling in the walls. Internal walls and partitions by double line outline only.*
- ☐ *Note all windows (WI), clerestories (CL) and skylights (SK). Note Type of each.*
- ☐ *Provide dimensions for all walls, windows, partitions and furniture* ***in Black***
- ☐ *Mark Reflectances for all surfaces seen in plan view* ***in Red***

Date: 11-30-2007 Bldg Name: ___ Surveyor Initials: DB/GG
Host Name: ___ Phone: ___

SPACE REFLECTED CEILING PLAN



First Floor

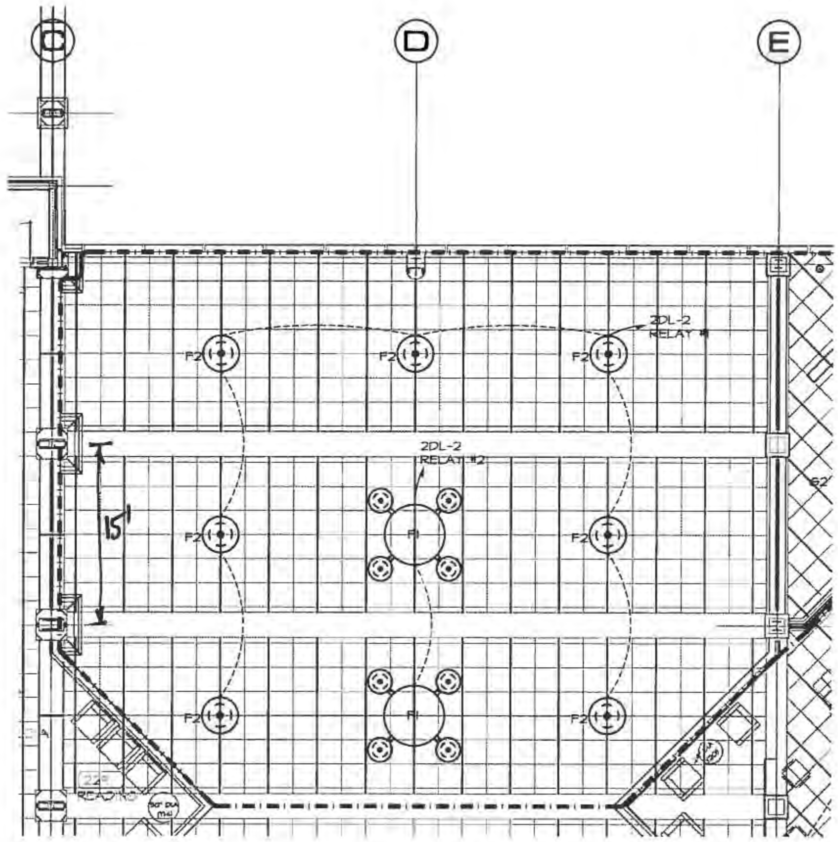
C2 - 7-3/4" aperture x 11-9/16" deep recessed downlight, aluminum housing, specular clear Alzak reflector w/white flange trim, single fused, (1) 42W triple tube vertical lamp, (1) electronic ballast, provide emergency ballast packs and remote test switches where noted on drawings, 277V, UL listed. (Prescolite: CFT842EB-WTF802H-SL-WT)

- ☐ *Sketch out reflected ceiling plan showing skylights (identify with a X), roof ridges, light fixtures, slopes*
- ☐ *Show MAGNETIC NORTH arrow*
- ☐ *Note all skylights (SK). Note Type of each.*
- ☐ *Provide dimensions*
- ☐ *Sketch location of light fixtures and show control zones for lighting in relation to windows*

Date: 11-30-2007 Bldg Name: Surveyor Initials: DB/GG

Host Name: Phone:

SPACE REFLECTED CEILING PLAN



Second Floor

F1 - Large pendant hung decorative fixture with overall diameter of 120" with (4) 30" diameter luminaries each with (6) 26-watt compact fluorescent lamps, die-cast link components, solid spun bowls. Fixture shall have two tiered ring with bowls mounted above ring, single mounting point. (SPI: AIP2406-fF26-277-PTXX-TL)

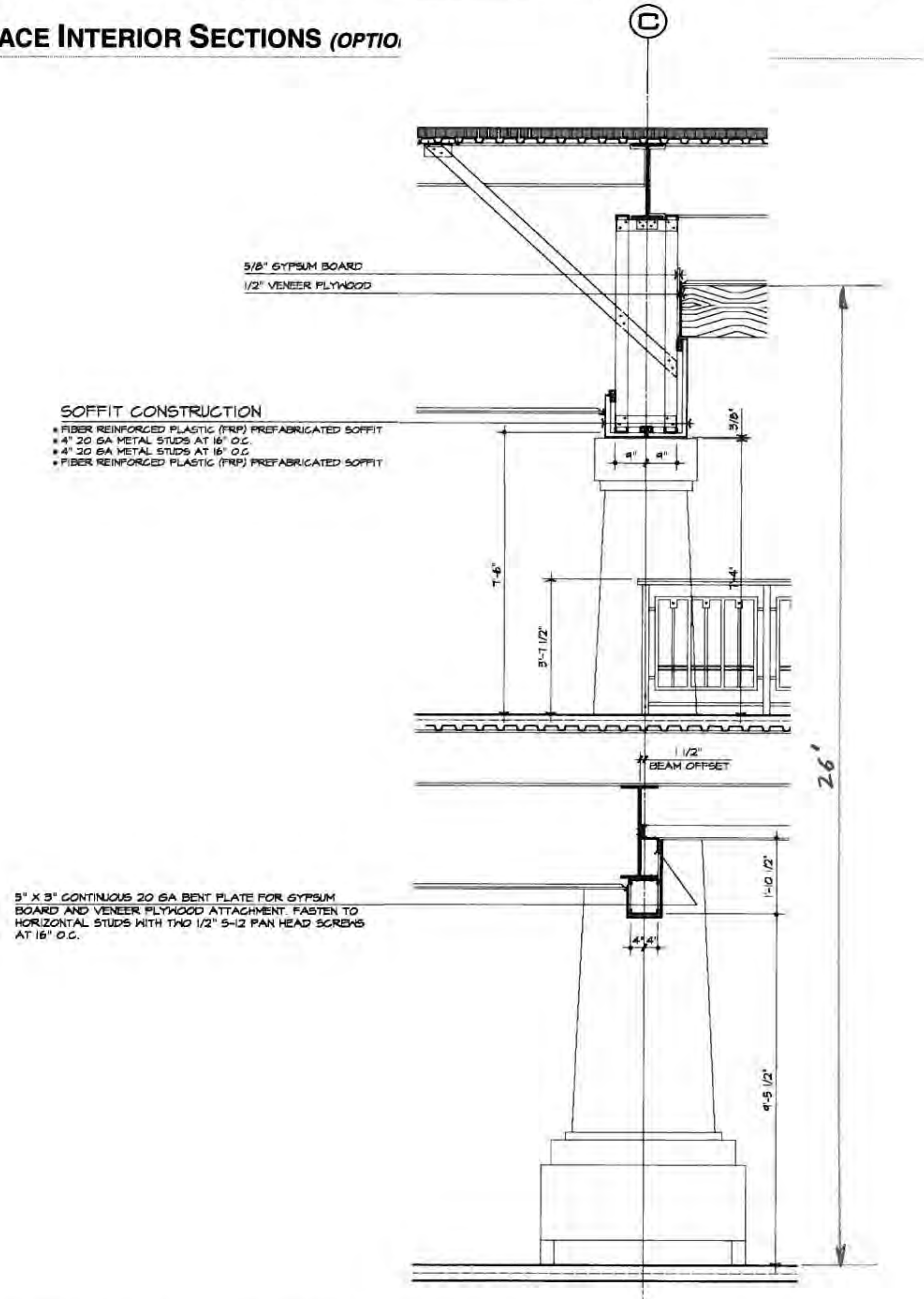
F2 - Large pendant hung direct/indirect decorative fixture with 36" diameter bowl with 10" apertured opening in center of bowl with illuminated baffles. Each fixture shall have (8) 42-watt compact fluorescent lamps. All suspension components shall have matte black finish; bowls shall have a brushed aluminum finish. Overall fixture height not to exceed 24" (Shaper Lighting: No. 429)

- ☐ *Sketch out reflected ceiling plan showing skylights (identify with a X), roof ridges, light fixtures, slopes*
- ☐ *Show MAGNETIC NORTH arrow*
- ☐ *Note all skylights (SK). Note Type of each.*

Date: 11-30-2007 Bldg Name: ___ Surveyor Initials: DB/GG

Host Name: ______ Phone: ______

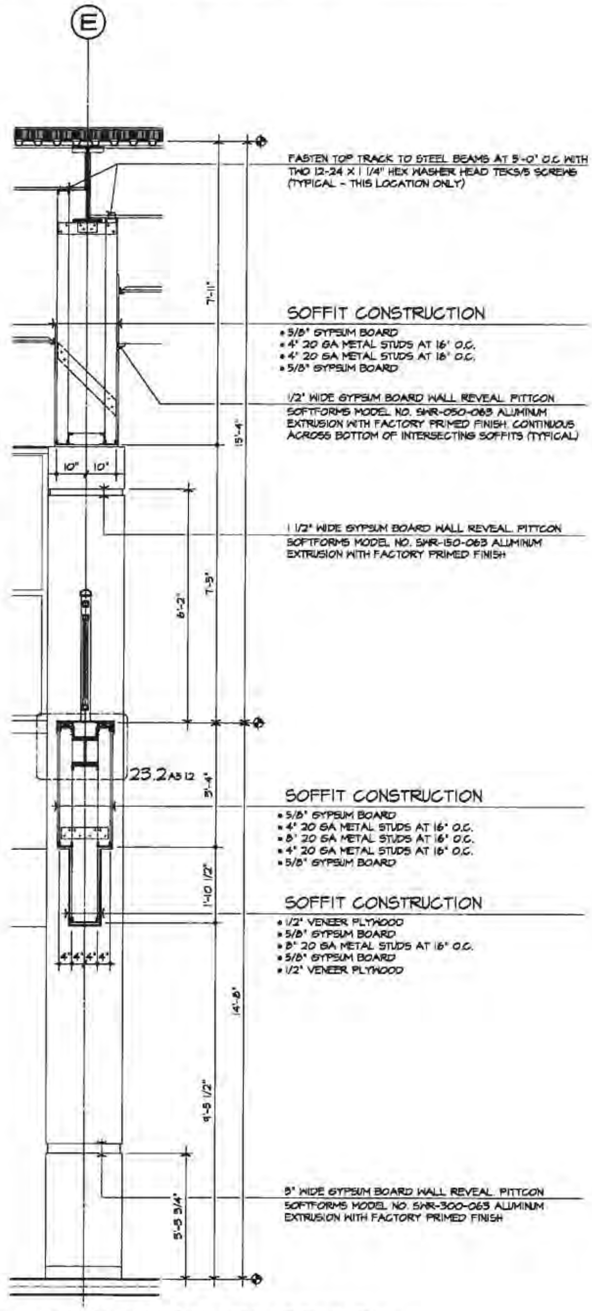
SPACE INTERIOR SECTIONS *(OPTIO*



Date: 11-30-2007 Bldg Name: Surveyor Initials: DB/GG

Host Name: Phone:

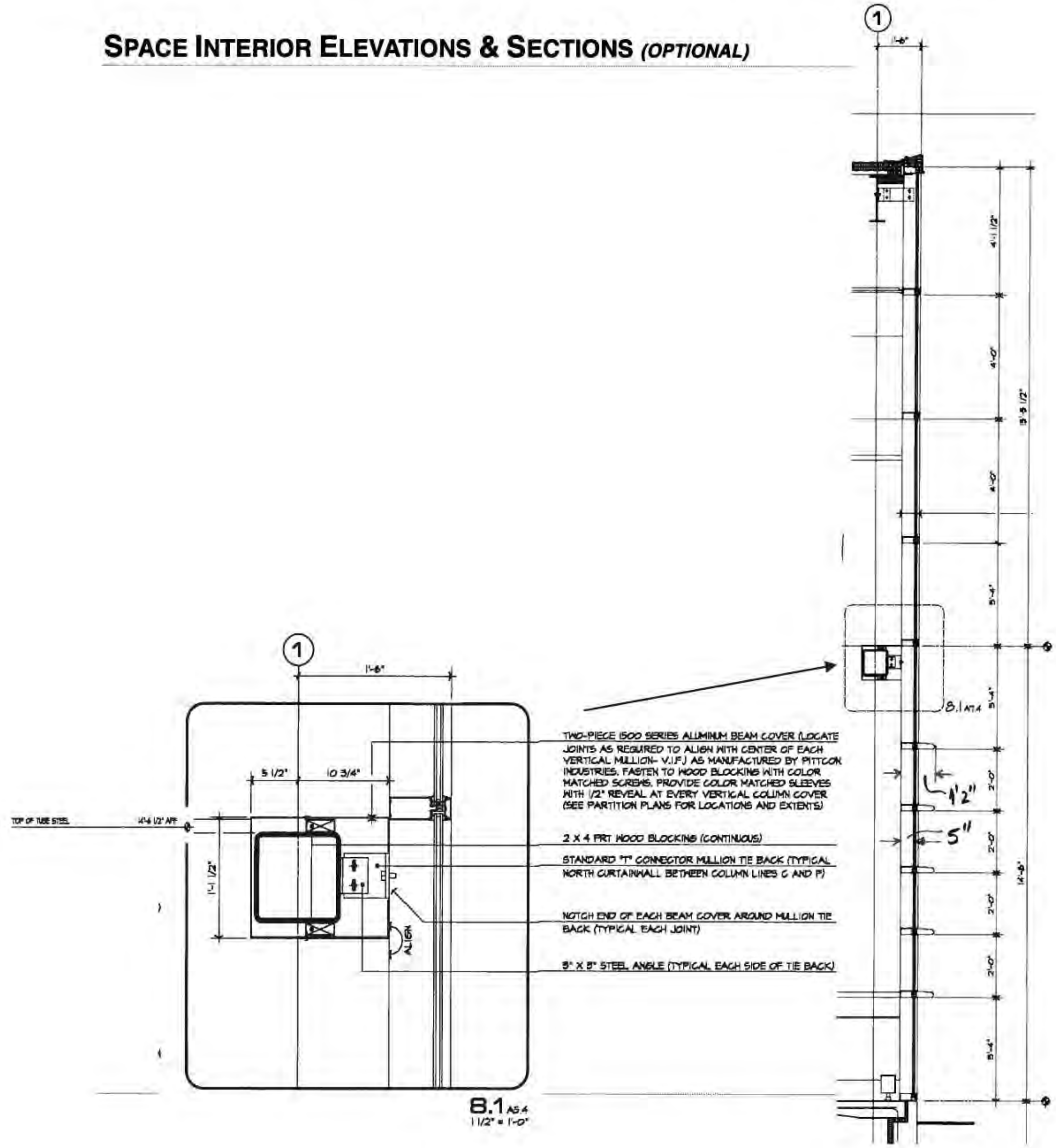
SPACE INTERIOR SECTIONS *(OPTIONAL)*



Date: 11-30-2007 Bldg Name: Surveyor Initials: DB/GG

Host Name: Phone:

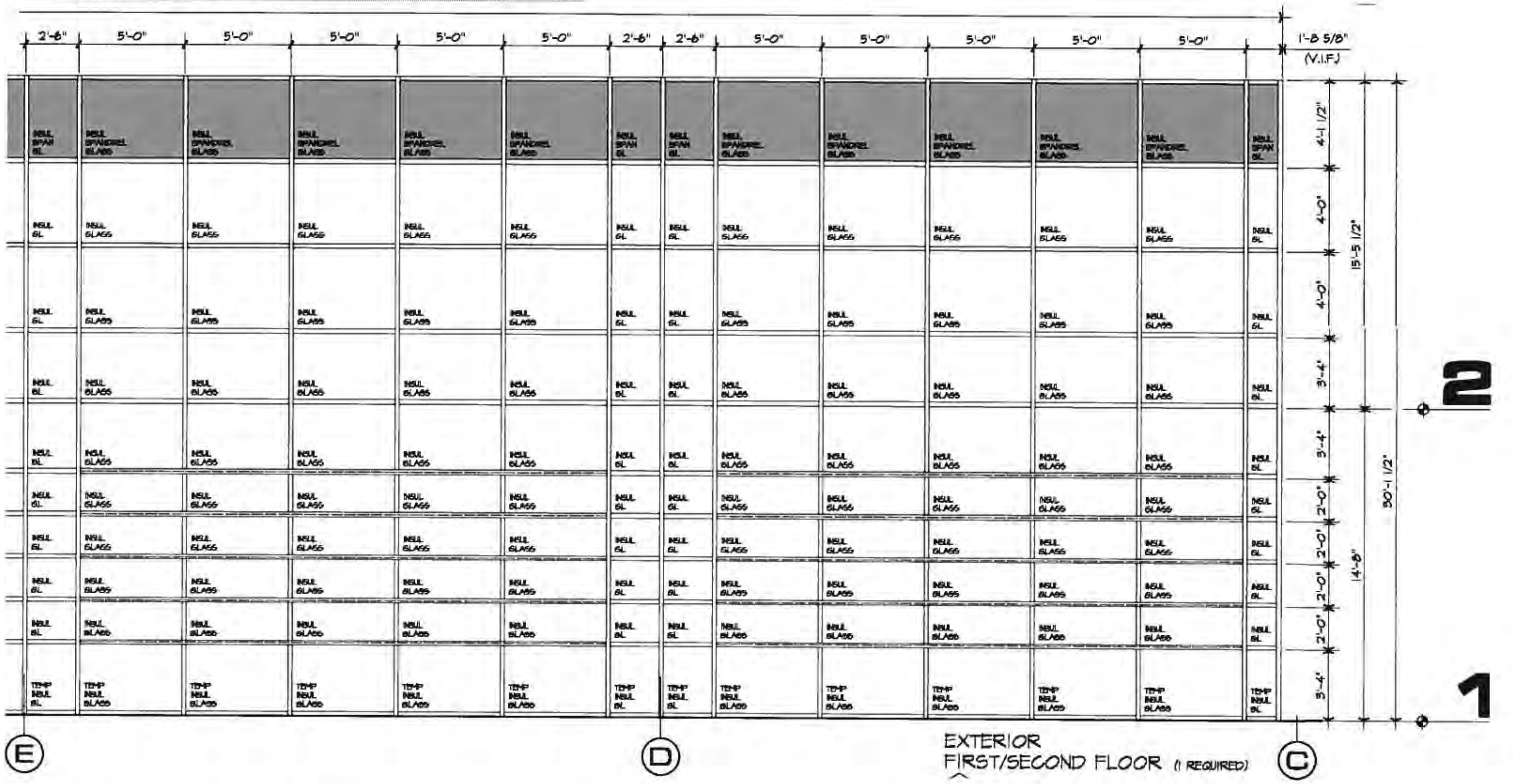
SPACE INTERIOR ELEVATIONS & SECTIONS *(OPTIONAL)*



Date: 11-30-2007 Bldg Name: Surveyor Initials: DB/GG

Host Name: Phone:

WINDOW ELEVATIONS AND DETAILS



- Draw elevation of each window type identified in plan.
- Note dimensions of overall window, frame thickness and thickness of mullions, transoms and other window elements that will reduce glass area that are over 4" thick.
- Subtract thickness of frame, mullions etc that are less than 4" wide from overall window dimensions
- Draw section showing overhangs, light-shelves, wall thickness, column thickness etc around the windows.
- Show height of window from floor, and distance between ceiling and top of window in section and elevation

WINDOW ELEVATIONS AND DETAILS

Refer to Page 10

- ☐ *Draw elevation of each window type identified in plan.*
- ☐ *Note dimensions of overall window, frame thickness and thickness of mullions, transoms and other window elements that will reduce glass area that are over 4" thick.*
- ☐ *Subtract thickness of frame, mullions etc that are less than 4" wide from overall window dimensions*
- ☐ *Draw section showing overhangs, light-shelves, wall thickness, column thickness etc around the windows.*
- ☐ *Show height of window from floor, and distance between ceiling and top of window in section and elevation.*

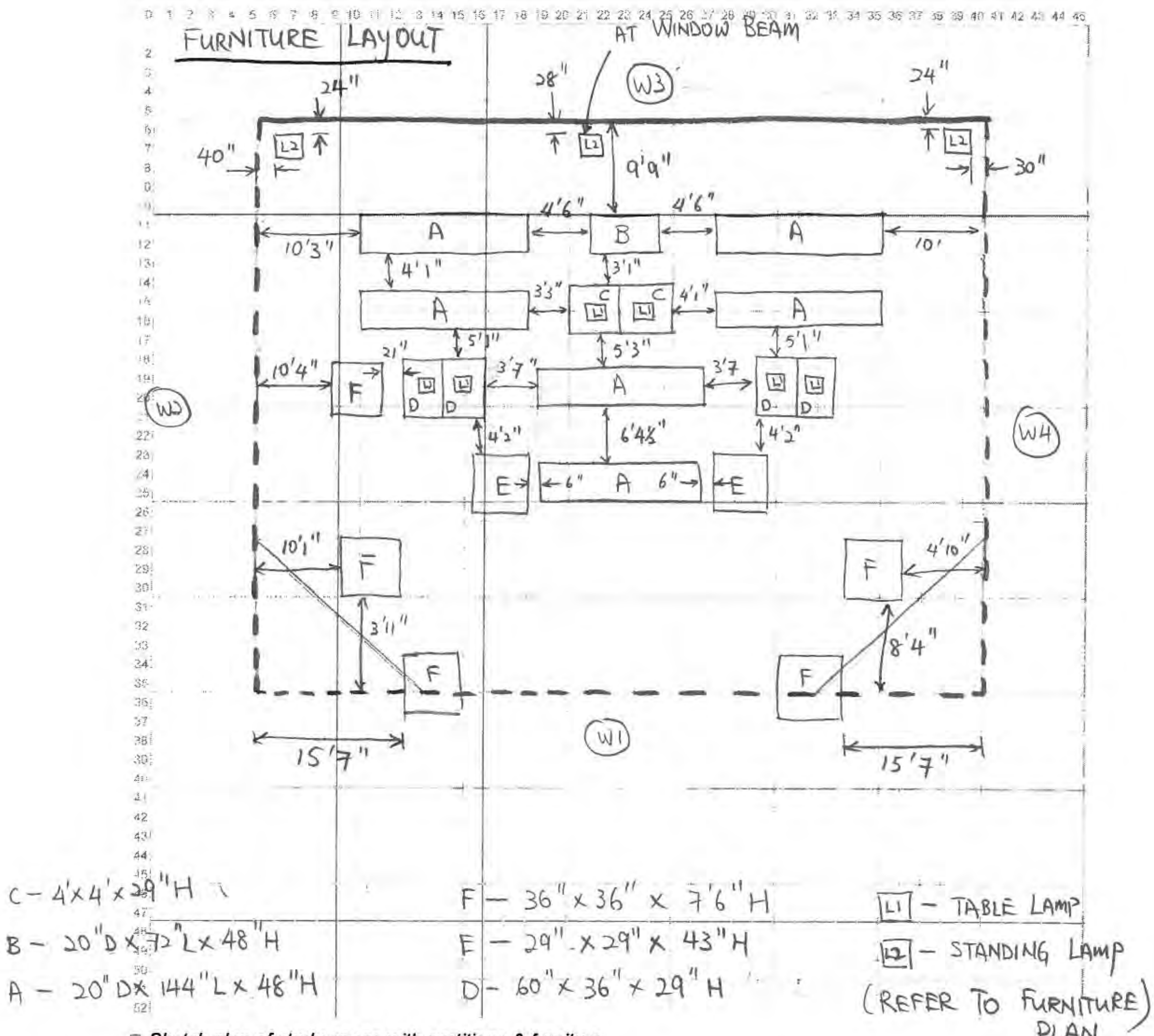
FURNITURE DIMENSIONS

Refer to Attached

NOTES:

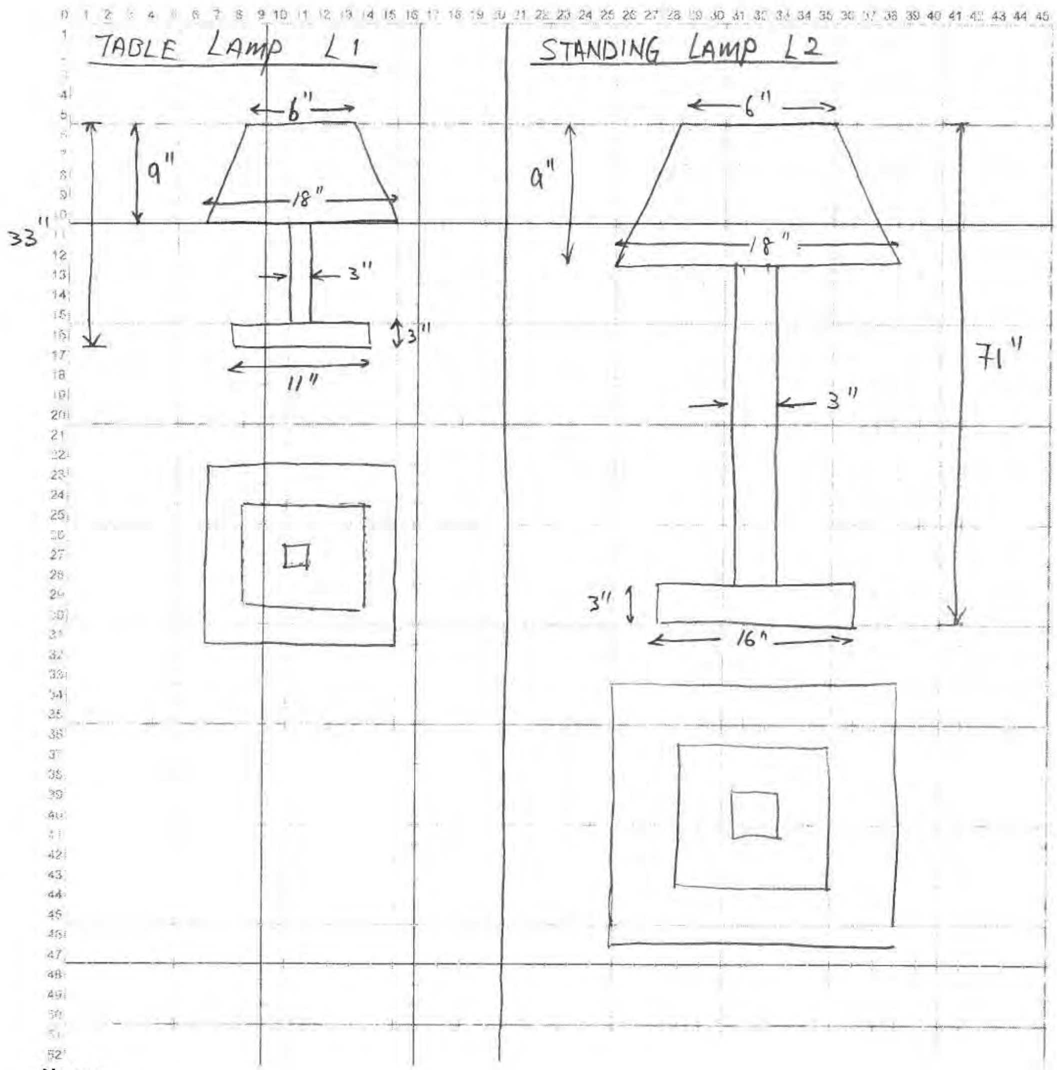
- ☐ *Show Plan, Section and Elevation of furniture over 4' in dimension.*
- ☐ *Note surface properties and reflectances for furniture surfaces.*

SPACE PLAN



- ☐ *Sketch plan of study space with partitions & furniture.*
- ☐ *Show MAGNETIC NORTH arrow*
- ☐ *Mark Wall 1 as wall with entrance to space (may be an air wall), Wall 2, 3, and 4 are marked clock wise* W1
- ☐ *Highlight exterior walls by filling in the walls. Internal walls and partitions by double line outline only.*
- ☐ *Note all windows (WI), clerestories (CL) and skylights (SK). Note Type of each.*
- ☐ *Provide dimensions for all walls, windows, partitions and furniture **in Black*** WI-1 SK-1 CL-1
- ☐ *Mark Reflectances for all surfaces seen in plan view **in Red***

FURNITURE DIMENSIONS



NOTES:

- ☐ *Show Plan, Section and Elevation of furniture over 4' in dimension.*
- ☐ *Note surface properties and reflectances for furniture surfaces.*

FENESTRATION MATERIAL PROPERTIES

Fenestration No.	Number of Layers	Framing Material	Tint/Color	U-Factor/SHGC	VLT
WI-1 (Curtainwall)	¼ " thick float (tempered where required) glass enclosing a hermitically sealed dehydrated ½ " air space	Aluminum	Evergreen	Summer daytime: 0.3 Winter nighttime: 0.29 Shading Coeff.: 0.42	67%

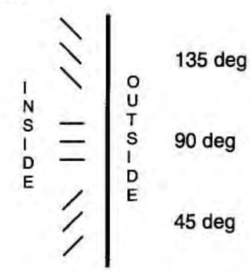
FENESTRATION TREATMENT

Fenestration No.	Interior Shading Type (HB/VB/C/S)	Color of Blinds/Curtain/ Shade	Width of typical slat in blinds	Describe specularity of Blind/Curtain/ Shade	VLT (Elec. Lights OFF) Outside Illumin.	VLT (Elec. Lights OFF)Reading of inside -facing blinds			
						0 deg	45 deg	90 deg	135 deg

Not Applicable

BLINDS AS OBSERVED - NOTE POSITION OF BLINDS BY WINDOW AS OBSERVED DURING SURVEY

Fenestration No.	Operation (% UP/Down and angle for blinds)	Fenestration No.	Operation (% UP/Down and angle for blinds)
Not Applicable		**Not Applicable**	



Envelope Material Properties

Element	Construction Type (surveyor's assessment)	Element thickness (look at window sill)	Outdoor Surface Material (describe)	Indoor Surface Material (describe)
		Refer to Interior Sections		

Electric Lighting

ELECTRIC LIGHTING SYSTEM 1: **Large pendant decorative fixture with diameter of 120-inch**

Count 7 # luminaires : 8 lamps/luminaire

Number of lamps off: 0/56 (AS FOUND)

% Dimmed ☑ 0% ☐ 25% ☐ 50% ☐ 75% ☐ 100% (AS FOUND)

Luminaire Type Lamp Type: 42W CFT Lamp Wattage: 42W ☐ can't tell

☐ prismatic ☐ louvered

☑ suspended ☐ recessed ☐ surface mount

mounting ht : 23' % down light: 5 %

Luminaire Condition ☐ deteriorated/yellowed ☐ aged ☐ average ☑ good

Ballast ☐ magnetic ☑ electronic ☐ can't tell

Lighting Controls ☐ 1 switch ☐ 2+switch ☑ photosensor ☐ dimmer ☐ oc sen

ELECTRIC LIGHTING SYSTEM 2: **Large pendant direct/indirect decorative fixture with 36-in diameter bowl**

Count 2 # luminaires : 24 lamps/luminaire

Number of lamps off: 0/48 (AS FOUND)

% Dimmed ☑ 0% ☐ 25% ☐ 50% ☐ 75% ☐ 100% (AS FOUND)

Luminaire Type Lamp Type: 26W CFT Lamp Wattage: 26W ☐ can't tell

☐ prismatic ☐ louvered

☑ suspended ☐ recessed ☐ surface mount

mounting ht : 23' % down light: 0 %

Luminaire Condition ☐ deteriorated/yellowed ☐ aged ☐ average ☑ good

Ballast ☐ magnetic ☑ electronic ☐ can't tell

Lighting Controls ☐ 1 switch ☐ 2+switch ☑ photosensor ☐ dimmer ☐ oc sen

ILLUMINANCE READINGS

Turn off the lights in the room, if acceptable to occupants/owner. If the lights cannot be turned off, then leave lights in AS FOUND condition. If window covers were completely closed, open them completely, otherwise leave them in their AS FOUND condition

Window Covers ☐ OPENED COMPLETELY ☑ AS FOUND

SET 1 – ELEC. LIGHTS OFF

WALL 1 (Air-wall)

13.8	19.4	10.9
9.7	18.6	13.3
10.2	16.8	13.0

WALL 2

6.2	22.1	43.7
6.8	14.8	16.8
8.2	14.4	15.4

WALL 3 (Full Window : WI-1)

4.9	6.5	9.5
4.6	5.1	11.5
5.0	5.2	9.2

WALL 4

24.0	11.8	4.5
23.4	14.0	3.0
18.5	10.8	2.6

FLOOR (W1 is up)

4.8	9.5	6.1
19.1	18.1	13.5
23.1	27.8	21.9

CUBIC at center of room

	3.4		
12.8	21.5	3.3	8.7
	40.5		

Facing window wall

SET 2 – ELEC. LIGHTS ON

WALL 1 (Air-wall)

20.6	28.0	18.3
17.5	26.9	21.7
18.0	24.74	23.9

WALL 2

11.5	26.7	29.8
14.1	21.3	21.8
13.5	24.1	19.2

WALL 3 (Full Window : WI-1)

14.3	15.7	14.8
15.8	14.6	15.5
17.2	14.14	15.4

WALL 4

34.1	23.3	16.4
20.8	26.2	13.6
19.5	22.4	12.5

FLOOR (W1 is up)

32.7	40.2	32.6
37.6	51.0	34.1
36.3	50.1	38.2

CUBIC at center of room

	19.5		
25.5	54.9	5.85	22.4
	54.3		

Facing window wall

Space Occupancy Schedule

Collect data on space occupancy using interviews with occupants or building management.

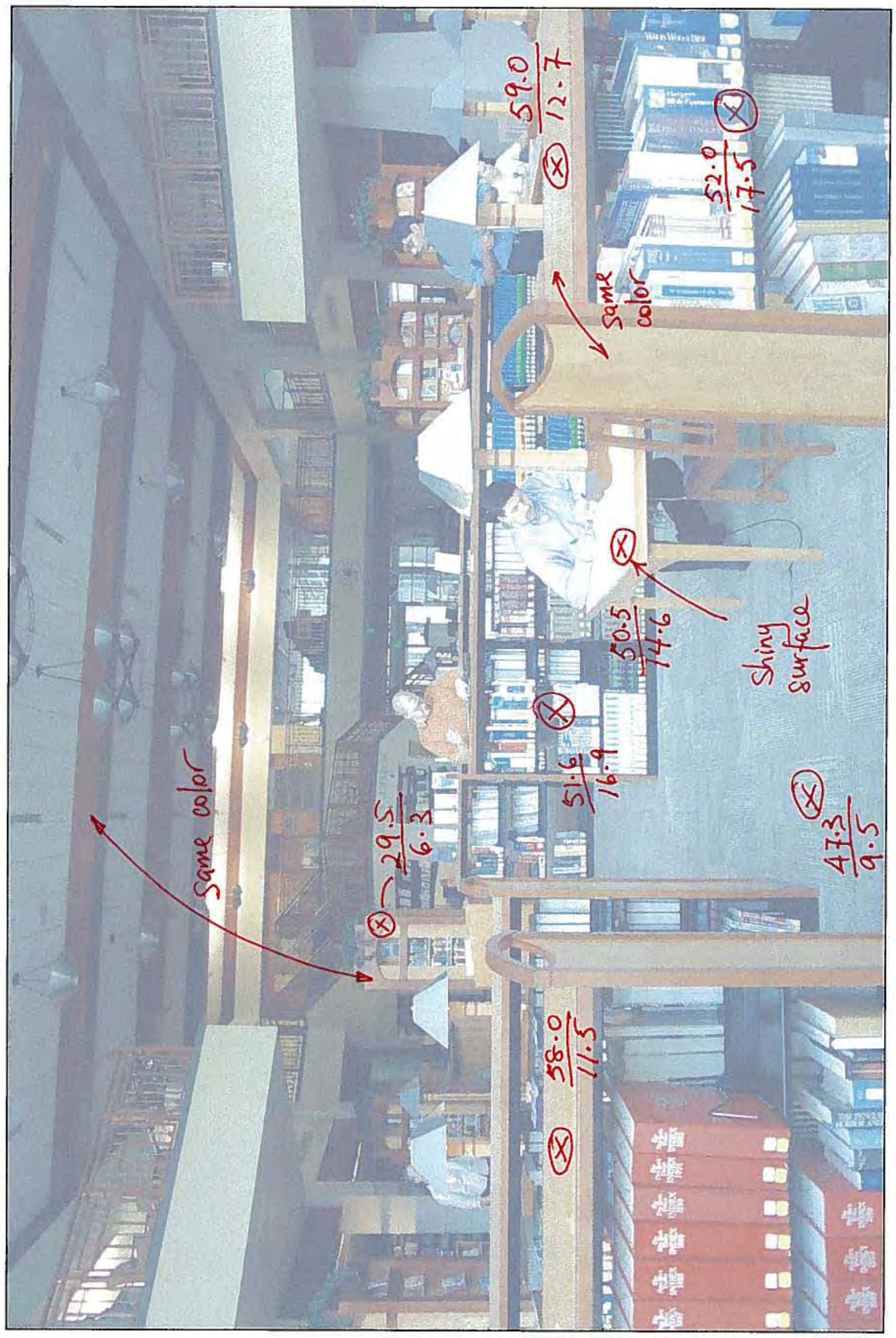
Note Weekday vs. Weekend and also seasonal variations in schedules

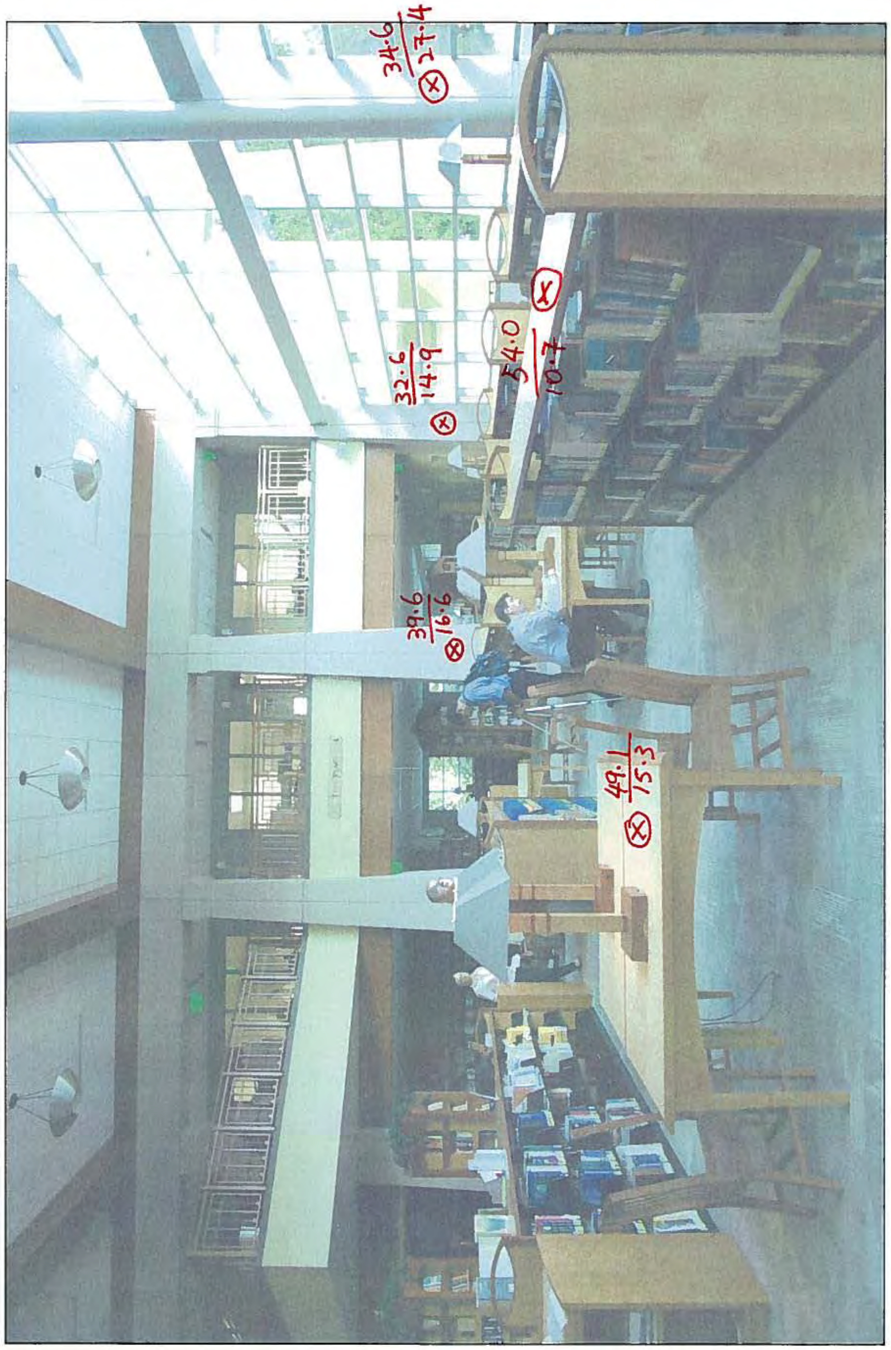
Monday to Thursday:	9:00 AM to 8:30 PM
Friday:	10:00 AM to 6:00 PM
Saturday:	9:00 AM to 5:00 PM
Sunday:	12:00 PM to 5:00 PM
Public Holidays:	Closed (New Year , Memorial, Veteran's, Christmas Eve & Christmas, Presidents, Independence, Thanksgiving, Easter, Labor) Closes at 5:00 PM on Thanksgiving and New Year's Eve

July & August

Saturday:	9:00 AM to 5:00 PM
Sunday:	Closed

General Notes:


59.0
12.7
52.0
17.5
same color
same color
29.5
6.3
51.6
16.9
50.5
14.6
shiny surface
47.3
9.5
58.0
11.5


34.6
27.4
32.6
14.9
54.0
10.7
39.6
16.6
49.1
15.3


38.6/26.7
54.7/10.4
19.2/9.3
16.6/7.9
55/12.5
41.6/12.3


40.3
11.5
17.0
30.9
55.0
10.6


WINDOW FRAME
AND LEDGES - ALUMINUM
SEMI-SPECULAR
53.3
10.4

SEMI-
IRCLE TILE
FLOOR IN
SPACE

APPENDIX B:
Survey Data

B-1 IES DMC Members and Experts at site visits

B-1.1 Experts at Site Visits

IES Daylight Metrics Subcommittee members and other daylighting experts participating in the site surveys:

Expert Name	Spaces Surveyed
Lisa Heschong	61
Joel Loveland	61
Kevin Van Den Wymelenberg	61
George Loisos	30
Marilyn Andersen	28
Christoph Rheinhart	19
Chris Meek	13
Neall Digert	10
Marsha Walton	8
Edward Bartholomew	8
Eleanor Lee	7
Matthew Tanteri	7
Connie Buchan	3
Davidson Norris	2
Russ Leslie	2

IES DMC Members

Members:

- Lisa Heschong (Chair)
- Kevin Van Den Wymelenberg (Vice Chair)
- Marilyne Andersen
- Neall Digert
- Luis Fernandez
- Amy Keller
- Eleanor Lee
- Joel Loveland
- Hayden McKay

- Rick Mistrick
- Bruce Mosher
- Christoph Reinhart
- Matthew Tanteri

Associate Members:

- Jim Ashmore
- Liliana Beltran
- John Bos
- Dale Bentrup
- David Eijadi
- George Loisos
- John Mardaljevic
- Konstantinos Papamichael
- Zach Rogers
- Marsha Walton

Adhoc Daylighting Code Coordinating Committee

- Lisa Heschong; IES Daylight Metrics, Title 24, CIE Daylight Simulation
- Kevin Van Den Wymelenberg, IES Daylight Metrics
- Jack Bailey, IgCC-SBTC
- Nancy Clanton, LEED IEQ
- Nick Ferzacca, ASHRAE 189
- Mark Frankle, IECC
- Eric Richman, ASHRAE – lighting
- Mudit Saxena, Title 24
- Len Sciarra, ASHRAE – envelope
- Prasad Vidya, LEED IEQ
- Keith Yancy, IgCC

B-2 CIE TC 3-27, Climate-Based Daylight Modelling

In December 2008 the CIE Board of Administration approved the formation of Division 3 Technical Committee **3-47: Climate-Based Daylight Modelling (CBDM)**. The terms of reference are:

1. To describe the state-of-the-art in CBDM and determine levels of research activity
2. To identify themes in ongoing areas of CBDM research and forecasting of future developments
3. To identify key areas of core or supporting research which are either lacking or with insufficient activity
4. To determine key application areas for CBDM and the required data pre-requisites
5. To codify an authoritative workflow for CBDM that is compliant with agreed quality assurance criteria
6. To provide guidance on the application of CBDM to predict emerging daylight metrics

A four year duration for the TC is anticipated.

The TC members are:

John Mardaljevic (chair)	**IESD, De Montfort, UK**	A
Marilyne Andersen (sec)	MIT, USA	A
Francesco Anselmo	Arup, UK	A
Magali Bodart	Catholic University of Louvain, Belgium	A
Ricardo Cabus	Universidade Federal de Alagoas, Brazil	A
Jens Christoffersen	SBI, Denmark	C
Dominique Dumortier	ENTPE, France	C
Robert Guglielmetti	NREL, USA	A
Lisa Heschong	Heschong Mahone Group, USA	C
Eleanor Lee	LBNL, USA	A
Amelie Martinez	ENTPE, France	A
Michel Perraudeau	ENTPE, France	C

Christoph Reinhart	Harvard, USA	A
Nicolas Roy	VELUX, Denmark	A
Jan Wienold	Fraunhofer, Freiburg, Germany	A
Stephen K Wittkopf	NUS, Singapore	A

A = active, C = corresponding

The proposal document for the TC can be downloaded from the CIE Division 3 website.

B-3 Descriptive Statistics and Survey Data

space	N.Occupan	OAMin	OAMean	OAStdDev	OAMax	OBMin	OBMean	OBStdDev	OBMax	OCMin	OCMean	OCStdDev
nyc01sp1	14	5	8.154	1.214	9	7	8.682	0.643	9	1	6.000	4.359
nyc01sp2	3	6.5	7.167	0.577	7.5	1	3.333	2.255	5.5	8	8.500	0.707
nyc02sp1	9	5	7.063	1.321	9	4.5	7.000	1.648	9	5	6.875	1.808
nyc02sp2	22	3	6.227	1.875	9	2	5.048	1.491	7.5	2	5.500	1.921
nyc04sp1	7	4	7.286	1.868	9	6	8.000	1.118	9	5	7.429	1.272
nyc04sp2	12	4	7.000	1.430	9	5	7.318	1.401	9	1	4.917	2.778
nyc05sp1	6	2.5	5.667	1.693	7.5	1	4.600	2.302	7	1	3.667	2.422
nyc05sp2	5	5	6.100	1.140	8	5	5.200	0.447	6	1	2.400	1.342
nyc08sp1	2	5	7.000	2.828	9	4.5	6.000	2.121	7.5	5	5.500	0.707
nyc08sp2	3	8	8.667	0.577	9	6	7.667	1.528	9	7	7.333	0.577
nyc09sp1	6	5.5	7.500	1.342	9	8	8.750	0.418	9	3	5.333	3.215
sea01sp1	8	5	7.125	1.246	9	5	6.875	1.575	9	2	6.286	2.498
sea01sp2	7	4	7.429	1.694	9	5	7.857	1.492	9	3	5.714	1.976
sea01sp3	7	6	7.357	0.748	8	6	7.714	1.220	9	3	5.857	1.952
sea02sp1	1	9	9.000	NA	9	7.5	7.500	NA	7.5	7	7.000	NA
sea02sp2	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea02sp3	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea03sp1	6	1	4.667	1.941	6	4	7.083	2.154	9	4	5.167	1.169
sea03sp2	19	4	7.053	1.189	9	3.5	6.100	1.983	9	2	5.000	2.121
sea04sp1	3	6.5	7.500	0.866	8	6	6.500	0.500	7	3	3.000	NA
sea04sp2	2	6	6.500	0.707	7	8	8.000	0.000	8	7	7.000	0.000
sea06sp1	4	5.5	7.125	1.250	8.5	9	9.000	0.000	9	7	8.500	1.000
sea06sp2	7	4	6.571	1.644	9	8	8.667	0.516	9	6	7.286	0.756
sea06sp3	3	8	8.667	0.577	9	8.5	8.833	0.289	9	5	7.333	2.082
sea06sp4	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea07sp1	8	7.5	8.000	0.535	9	8	8.813	0.372	9	7	8.250	0.886
sea07sp2	3	6.5	7.500	0.866	8	6	7.167	1.041	8	5	5.667	1.155
sea07sp3	6	5	7.417	1.744	9	6.5	8.250	1.037	9	5	5.000	NA
sfo01sp1	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sfo01sp2	22	5	8.556	1.294	9	5.5	6.250	1.061	7	6	7.500	2.121
sfo01sp4	19	2	6.789	2.281	9	2.5	6.947	2.260	9	1	6.158	2.566
sfo02sp1	28	5	8.000	1.122	9	2	7.161	1.968	9	3	7.607	1.618
sfo02sp3	29	3	6.611	1.577	9	1.5	6.519	1.939	9	1	6.370	2.290
sfo04sp1	12	5	6.958	1.544	9	5.5	7.708	1.422	9	1	7.167	2.250
sfo04sp2	12	4.5	7.000	1.365	9	4	7.409	1.281	9	6	7.909	1.044
sfo05sp1	5	4.5	8.000	1.969	9	6.5	7.333	0.764	8	6	7.333	1.528
sfo05sp2	4	5	5.833	1.041	7	4	5.500	2.121	7	1	1.000	NA
sfo05sp3	2	6.5	7.250	1.061	8	6	6.000	NA	6	Inf	NA	NA
sfo05sp4	5	5	7.100	1.597	9	2	5.750	2.872	8	5	7.000	1.732
sfo06sp1	8	3.5	6.500	1.890	8.5	1	4.500	3.082	8	1	2.250	2.500
sfo06sp2	8	5	7.750	1.488	9	1.5	5.700	2.797	8.5	9	9.000	NA
sfo07sp1	7	7	7.714	0.393	8	4.5	7.083	1.497	8	5	7.000	1.414
smf02sp1	13	3.5	7.000	1.610	9	7	8.409	0.701	9	1	1.000	NA
smf03sp1	20	7	8.400	0.940	9	3	6.474	1.982	9	1	1.000	NA
smf03sp2	30	1	6.621	2.194	9	2	7.350	1.957	9	2	6.655	2.424
smf04sp1	6	5	6.417	1.281	8	5	6.750	1.541	9	5	6.833	1.472
smf04sp2	8	3.5	6.750	2.000	9	3	6.429	2.652	9	5	7.167	1.602
smf04sp3	12	4.5	7.273	1.421	9	6	7.750	0.979	9	1	5.900	2.644
smf05sp1	8	3	5.938	2.145	8.5	1	3.917	2.577	7	3	3.000	NA
smf06sp1	17	2.5	5.313	1.493	9	1	4.706	2.222	9	1	4.563	2.898
smf06sp2	14	5	6.786	1.762	9	1	4.929	2.941	9	3	8.500	1.605
smf06sp3	26	1	4.396	2.126	9	1	3.591	2.186	7.5	1	4.130	2.546
smf07sp1	10	5	7.500	1.491	9	6.5	8.250	0.791	9	5	8.000	1.549
smf08sp1	18	5.5	7.444	0.998	9	2	7.438	1.797	9	4	7.222	1.629
smf08sp2	6	5	7.167	1.633	9	4	7.500	1.949	9	5	7.167	1.835
smf08sp3	28	4	6.821	1.285	9	4	7.768	1.316	9	4	7.643	1.569
smf09sp1	10	3	5.400	1.410	7.5	5	7.000	1.541	9	1	6.333	3.445
smf10sp1	2	7	8.000	1.414	9	8.5	8.750	0.354	9	Inf	NA	NA
smf10sp2	3	4	5.000	1.000	6	5	7.000	2.828	9	9	9.000	NA
smf11sp1	18	5	7.556	0.922	9	5	7.361	1.122	9	1	7.111	2.083
smf11sp2	1	6	6.000	NA	6	8	8.000	NA	8	Inf	NA	NA

space	OCMax	ODMin	ODMean	ODStdDev	ODMax	OEMin	OEMean	OEStdDev	OEMax	OFMin	OFMean	OFStdDev
nyc01sp1	9	1	4.864	2.820	9	2.5	6.857	2.033	9	3	7.458	2.061
nyc01sp2	9	1	1.167	0.289	1.5	2.5	4.000	1.323	5	2.5	5.833	2.930
nyc02sp1	9	3.5	5.500	1.893	9	3	5.125	1.620	8	1	4.250	2.035
nyc02sp2	8	1.5	4.886	1.845	9	4	5.667	0.827	7.5	4.5	6.864	1.338
nyc04sp1	9	6	7.750	1.084	9	2	6.429	2.130	8	3	6.571	1.790
nyc04sp2	9	2.5	5.182	2.283	8	2.5	5.417	2.214	9	2.5	5.792	2.105
nyc05sp1	7	3.5	4.900	1.194	6.5	1	3.750	1.782	6	1	3.583	2.940
nyc05sp2	4	1	2.700	1.304	4.5	2	3.500	1.225	5	1	2.700	1.204
nyc08sp1	6	4.5	5.000	0.707	5.5	4.5	4.500	0.000	4.5	5	5.250	0.354
nyc08sp2	8	2	4.167	2.021	6	3	3.750	1.061	4.5	4.5	6.167	1.443
nyc09sp1	9	1.5	4.833	2.893	9	3	4.333	1.506	7	2	4.333	2.944
sea01sp1	9	2	6.125	2.167	9	6	7.000	0.926	8.5	4	6.438	1.841
sea01sp2	9	3	5.500	2.121	8	4.5	6.286	1.113	8	3.5	6.143	1.547
sea01sp3	9	2	4.714	2.018	8.5	5	5.643	0.476	6.5	4.5	7.143	1.600
sea02sp1	7	6.5	6.500	NA	6.5	4.5	4.500	NA	4.5	2.5	2.500	NA
sea02sp2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea02sp3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea03sp1	7	5.5	6.833	0.931	8	3	4.083	1.201	6	2	3.417	1.985
sea03sp2	7	3	7.853	1.498	9	5	7.382	1.206	9	3	7.556	1.542
sea04sp1	3	7.5	8.250	1.061	9	5	5.833	1.443	7.5	4	5.500	1.803
sea04sp2	7	6	7.000	1.414	8	6	6.750	1.061	7.5	6.5	7.250	1.061
sea06sp1	9	4.5	6.625	1.548	8	5	6.125	1.315	7.5	1	6.000	3.391
sea06sp2	8	1	4.429	2.388	7.5	3.5	4.929	1.305	7.5	1	3.286	2.119
sea06sp3	9	7	7.667	0.764	8.5	3	4.667	1.528	6	2	4.167	2.021
sea06sp4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea07sp1	9	3.5	6.563	1.898	9	1	5.375	2.134	7.5	1	5.063	2.162
sea07sp2	7	3.5	5.000	1.323	6	1.5	3.667	1.893	5	2	3.500	1.500
sea07sp3	5	5	7.000	1.633	9	5	6.917	1.686	9	5.5	8.083	1.357
sfo01sp1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sfo01sp2	9	5.5	6.500	1.414	7.5	4	5.500	2.121	7	4.5	6.250	2.475
sfo01sp4	9	1	6.211	2.423	9	2	5.947	2.327	9	1	5.316	3.318
sfo02sp1	9	4	7.981	1.308	9	4.5	7.759	1.477	9	5	7.778	1.354
sfo02sp3	9	1	5.780	2.363	9	3	6.611	1.977	9	2	5.732	2.307
sfo04sp1	9	1	5.917	2.627	9	2.5	5.750	1.530	8	2.5	5.708	2.137
sfo04sp2	9	4	6.000	1.552	8.5	3.5	5.792	1.453	7.5	2.5	5.667	1.863
sfo05sp1	9	1.5	4.100	1.817	6	5	7.250	1.658	9	5	7.375	1.797
sfo05sp2	1	1	2.875	1.931	5	3	5.000	1.683	7	5.5	6.750	1.658
sfo05sp3	#NAME?	3	4.000	1.414	5	6.5	7.500	1.414	8.5	6.5	7.750	1.768
sfo05sp4	8	1	4.600	3.050	9	3	5.125	1.493	6.5	5	6.000	0.816
sfo06sp1	6	1	4.286	2.942	8	5	6.857	1.435	8.5	7	7.667	0.753
sfo06sp2	9	3	5.357	2.375	8.5	4	5.625	1.598	9	4	7.313	1.907
sfo07sp1	8	3	5.286	1.912	8	4.5	6.071	0.886	7	5.5	6.857	1.180
smf02sp1	1	2	3.958	1.559	8	4	5.333	1.052	7	6	7.417	0.925
smf03sp1	1	1	6.222	2.487	9	1	4.950	2.114	9	5.5	5.500	NA
smf03sp2	9	3	7.037	1.802	9	4.5	7.196	1.436	9	5.5	7.862	1.068
smf04sp1	9	4	7.000	2.025	9	4.5	5.400	0.822	6.5	6	7.200	0.908
smf04sp2	9	1	5.375	3.662	9	2.5	7.125	2.167	9	3.5	7.563	2.026
smf04sp3	9	3.5	4.545	1.011	7	2.5	6.458	1.994	8.5	4	7.167	2.049
smf05sp1	3	4.5	6.875	1.598	9	5.5	7.375	1.157	9	7.5	8.625	0.582
smf06sp1	9	1	4.676	2.772	9	2	6.118	2.162	9	5	7.294	1.601
smf06sp2	9	3	7.250	1.949	9	4.5	7.423	1.669	9	3.5	7.107	2.002
smf06sp3	8	2.5	5.130	1.835	9	4	7.024	1.260	9	4.5	7.500	1.475
smf07sp1	9	2.5	6.900	2.132	9	6.5	7.722	0.795	9	7	8.063	0.776
smf08sp1	9	5	7.306	1.087	9	3.5	6.583	1.448	9	6	7.583	0.809
smf08sp2	9	5	6.917	1.656	9	5.5	7.417	1.463	9	5.5	6.750	1.294
smf08sp3	9	3	6.857	1.514	9	1	6.268	1.970	9	1	7.125	1.894
smf09sp1	9	2	4.938	2.412	9	4.5	6.813	1.792	8.5	4	6.250	1.648
smf10sp1	#NAME?	7	7.250	0.354	7.5	5.5	6.500	1.414	7.5	7.5	8.250	1.061
smf10sp2	9	1	2.333	2.309	5	3	4.167	1.041	5	5	6.667	2.082
smf11sp1	9	3.5	7.139	1.616	9	4	5.944	1.316	8.5	2.5	7.417	1.751
smf11sp2	#NAME?	5	5.000	NA	5	6	6.000	NA	6	6	6.000	NA

space	OFMax	OAgeMin	OAgeMean	OAgeStdDe	OAgeMax	O3Min	O3Mean	O3StdDev	O3Max	O4Min	O4Mean	O4StdDev
nyc01sp1	9	12	48.167	19.305	78	1	3.357	1.906	7	1	2.357	0.842
nyc01sp2	8	70	70.000	NA	70	1	2.667	1.528	4	1	1.333	0.577
nyc02sp1	7.5	22	27.625	6.675	43	1	4.875	1.808	7	1	1.000	0.000
nyc02sp2	9	22	28.250	8.385	57	1	3.571	1.630	7	1	1.714	1.102
nyc04sp1	8	27	35.500	9.028	50	1	3.571	1.988	7	1	1.571	0.535
nyc04sp2	9	31	44.800	8.189	58	1	4.250	2.006	7	1	1.500	0.674
nyc05sp1	7.5	27	29.000	2.828	31	2	4.000	1.789	6	1	1.833	1.169
nyc05sp2	4	26	32.200	5.450	40	2	4.800	1.789	6	1	1.000	0.000
nyc08sp1	5.5	34	35.500	2.121	37	1	2.500	2.121	4	5	5.000	0.000
nyc08sp2	7	35	41.667	10.693	54	1	1.000	0.000	1	1	1.500	0.707
nyc09sp1	9	24	47.167	18.236	79	2	5.000	1.673	6	1	1.000	0.000
sea01sp1	9	24	34.625	11.338	58	1	3.750	1.165	5	1	1.750	0.707
sea01sp2	8	25	41.143	12.773	56	1	3.571	1.134	4	1	1.857	0.378
sea01sp3	8.5	26	32.000	4.761	39	1	3.429	1.134	4	1	1.571	0.535
sea02sp1	2.5	55	55.000	NA	55	4	4.000	NA	4	1	1.000	NA
sea02sp2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea02sp3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea03sp1	7	21	23.833	5.492	35	1	2.500	2.510	7	1	2.167	0.753
sea03sp2	9	18	28.389	10.001	52	1	3.000	2.211	7	3	3.263	0.562
sea04sp1	7.5	24	30.000	5.292	34	5	5.000	0.000	5	3	3.000	0.000
sea04sp2	8	24	28.000	5.657	32	5	5.000	0.000	5	1	1.500	0.707
sea06sp1	8.5	33	44.250	13.074	60	1	3.250	1.500	4	1	2.250	0.957
sea06sp2	6	40	47.333	8.571	61	1	2.714	1.604	4	1	2.429	0.976
sea06sp3	6	38	44.333	7.767	53	4	4.000	0.000	4	1	1.000	0.000
sea06sp4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea07sp1	8	25	44.250	13.199	67	4	4.375	1.061	7	1	1.625	0.744
sea07sp2	5	32	37.667	4.933	41	4	4.000	0.000	4	2	2.000	0.000
sea07sp3	9	33	43.833	7.574	56	3	3.667	0.516	4	2	2.333	0.516
sfo01sp1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sfo01sp2	8	7	9.227	7.406	37	1	2.818	0.588	3	1	1.000	0.000
sfo01sp4	9	9	9.158	0.375	10	3	3.500	0.707	4	1	1.000	NA
sfo02sp1	9	10	11.750	3.406	29	2	5.455	1.293	6	2	3.000	1.414
sfo02sp3	9	11	11.793	2.038	22	1	3.966	1.658	7	1	1.966	0.626
sfo04sp1	9	30	45.600	12.122	60	1	4.000	1.537	6	1	1.750	0.866
sfo04sp2	8	21	38.750	15.118	65	1	2.583	1.165	5	1	1.583	0.669
sfo05sp1	9	37	44.333	8.083	53	3	4.600	0.894	5	1	1.600	0.894
sfo05sp2	9	34	39.250	4.113	44	3	4.250	0.957	5	1	2.250	0.957
sfo05sp3	9	39	39.000	NA	39	3	3.000	0.000	3	3	3.000	0.000
sfo05sp4	7	45	51.667	6.506	58	1	1.400	0.894	3	1	2.000	1.414
sfo06sp1	9	20	41.375	13.742	61	1	4.375	1.598	6	2	3.500	1.069
sfo06sp2	9	43	49.400	7.162	61	4	5.250	1.035	6	3	3.000	0.000
sfo07sp1	8.5	22	39.571	13.855	64	1	4.429	2.507	7	2	2.571	0.535
smf02sp1	9	27	48.231	13.971	74	1	2.500	1.931	5	2	2.769	0.725
smf03sp1	5.5	8	10.600	11.628	60	4	4.000	0.000	4	2	2.000	0.000
smf03sp2	9	10	13.467	10.316	68	1	4.067	1.999	7	1	1.700	0.915
smf04sp1	8	46	55.750	7.805	65	1	2.833	2.041	5	1	1.500	0.837
smf04sp2	9	47	53.625	6.927	68	1	4.500	1.414	5	1	2.125	1.246
smf04sp3	9	28	44.727	13.070	62	1	3.250	2.137	7	1	1.583	0.669
smf05sp1	9	23	32.875	11.606	57	3	4.250	0.707	5	3	3.375	0.518
smf06sp1	9	14	23.235	14.877	57	1	2.412	1.121	5	1	1.882	1.054
smf06sp2	9	15	18.538	6.851	41	6	6.000	0.000	6	1	2.667	1.557
smf06sp3	9	14	15.167	0.917	17	2	4.308	1.850	6	1	2.480	1.327
smf07sp1	9	19	48.100	15.452	64	1	3.800	1.687	6	2	2.500	0.527
smf08sp1	9	13	14.706	4.997	34	1	3.333	2.567	7	1	1.889	0.758
smf08sp2	9	13	20.200	10.733	37	1	3.667	1.366	5	1	2.000	0.894
smf08sp3	9	12	14.222	5.176	40	2	2.464	1.290	7	1	1.926	0.730
smf09sp1	8.5	14	16.400	1.075	18	1	2.500	1.958	5	1	2.300	0.823
smf10sp1	9	50	55.000	7.071	60	1	2.500	2.121	4	1	1.500	0.707
smf10sp2	9	43	48.500	7.778	54	2	3.000	1.414	4	1	1.000	0.000
smf11sp1	9	17	37.625	12.137	58	1	2.222	1.833	5	1	2.111	0.758
smf11sp2	6	51	51.000	NA	51	3	3.000	NA	3	3	3.000	NA

space	O4Max	O5Min	O5Mean	O5StdDev	O5Max	O6Min	O6Mean	O6StdDev	O6Max	O7Min	O7Mean	O7StdDev
nyc01sp1	3	5	5.714	0.469	6	1	5.077	1.382	6	1	1.846	0.801
nyc01sp2	2	3	4.667	1.528	6	5	5.667	0.577	6	2	2.667	0.577
nyc02sp1	1	1	2.250	1.282	5	1	4.375	1.598	6	1	3.125	1.126
nyc02sp2	5	1	2.000	0.973	4	1	4.571	1.568	6	1	1.952	0.218
nyc04sp1	2	2	3.857	1.215	5	4	4.714	0.488	5	4	4.000	0.000
nyc04sp2	3	1	3.333	1.875	5	3	4.833	0.577	5	3	3.667	0.492
nyc05sp1	4	3	3.000	0.000	3	3	3.000	0.000	3	3	3.000	0.000
nyc05sp2	1	1	1.400	0.894	3	2	2.800	0.447	3	3	3.200	0.447
nyc08sp1	5	5	5.000	NA	5	5	5.000	NA	5	3	3.500	0.707
nyc08sp2	2	5	5.000	0.000	5	3	4.333	1.155	5	2	3.000	1.000
nyc09sp1	1	6	6.000	0.000	6	2	4.167	1.169	5	2	3.000	1.000
sea01sp1	3	1	4.500	1.512	6	4	5.429	0.787	6	3	3.857	0.378
sea01sp2	2	4	4.429	0.535	5	3	5.143	1.069	6	4	4.000	0.000
sea01sp3	2	5	5.000	0.000	5	2	4.429	1.397	6	3	3.714	0.488
sea02sp1	1	3	3.000	NA	3	5	5.000	NA	5	4	4.000	NA
sea02sp2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea02sp3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea03sp1	3	1	2.333	1.033	4	2	2.333	0.816	4	2	2.000	0.000
sea03sp2	5	3	5.579	0.769	6	1	4.000	2.380	6	1	1.294	0.588
sea04sp1	3	6	6.000	0.000	6	4	5.333	1.155	6	2	2.667	0.577
sea04sp2	2	3	4.000	1.414	5	4	5.000	1.414	6	1	1.000	0.000
sea06sp1	3	3	3.500	0.577	4	6	6.000	0.000	6	2	2.750	0.957
sea06sp2	4	4	4.857	0.690	6	5	5.857	0.378	6	3	3.571	0.535
sea06sp3	1	5	5.000	0.000	5	6	6.000	0.000	6	1	1.667	0.577
sea06sp4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea07sp1	3	2	2.500	0.535	3	4	5.500	0.756	6	3	3.625	0.518
sea07sp2	2	3	4.000	1.000	5	1	4.333	2.887	6	1	2.000	1.000
sea07sp3	3	6	6.000	0.000	6	5	5.833	0.408	6	3	3.833	0.408
sfo01sp1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sfo01sp2	1	4	4.000	0.000	4	4	4.091	0.426	6	3	3.045	0.213
sfo01sp4	1	4	4.000	NA	4	4	4.000	NA	4	3	3.000	NA
sfo02sp1	5	1	2.600	1.817	5	4	4.000	0.000	4	3	3.250	0.500
sfo02sp3	3	1	3.414	0.946	5	3	4.931	0.371	5	3	3.034	0.186
sfo04sp1	3	2	2.667	1.073	5	2	5.083	1.240	6	4	4.000	0.000
sfo04sp2	3	4	4.667	0.492	5	4	5.583	0.793	6	4	4.000	0.000
sfo05sp1	3	4	5.200	0.837	6	4	5.200	0.837	6	3	3.750	0.500
sfo05sp2	3	6	6.000	0.000	6	5	5.500	0.577	6	4	4.000	0.000
sfo05sp3	3	6	6.000	0.000	6	5	5.000	0.000	5	1	1.000	0.000
sfo05sp4	4	2	4.250	2.062	6	5	5.600	0.548	6	4	4.000	0.000
sfo06sp1	5	1	4.000	2.507	6	1	5.000	1.927	6	1	2.286	0.951
sfo06sp2	3	5	5.667	0.516	6	6	6.000	0.000	6	1	1.625	0.518
sfo07sp1	3	1	4.286	1.704	6	4	5.143	0.690	6	2	3.000	0.816
smf02sp1	4	6	6.000	0.000	6	5	5.923	0.277	6	2	2.923	0.760
smf03sp1	2	4	4.000	0.000	4	5	5.050	0.224	6	3	3.050	0.224
smf03sp2	5	1	4.367	1.129	5	1	5.100	0.885	6	2	3.103	0.489
smf04sp1	3	1	3.833	1.602	5	6	6.000	0.000	6	4	4.000	0.000
smf04sp2	4	4	4.625	0.518	5	2	5.500	1.414	6	3	3.750	0.463
smf04sp3	3	1	4.500	1.243	5	5	5.750	0.452	6	4	4.000	0.000
smf05sp1	4	4	5.571	0.787	6	5	5.875	0.354	6	3	3.625	0.518
smf06sp1	4	1	1.471	1.125	5	3	5.294	1.105	6	1	2.000	1.275
smf06sp2	5	1	1.333	1.155	5	4	5.333	0.888	6	2	2.250	0.622
smf06sp3	5	1	1.200	0.408	2	5	5.160	0.374	6	2	2.000	0.000
smf07sp1	3	5	5.600	0.516	6	1	5.000	2.108	6	1	2.100	1.370
smf08sp1	4	2	3.611	1.092	5	4	4.111	0.471	6	1	1.444	0.784
smf08sp2	3	3	4.500	0.837	5	3	5.333	1.211	6	1	1.333	0.816
smf08sp3	3	1	4.464	1.036	5	4	4.071	0.378	6	1	2.071	0.466
smf09sp1	4	5	5.000	0.000	5	1	3.500	2.635	6	1	1.000	0.000
smf10sp1	2	6	6.000	0.000	6	4	5.000	1.414	6	1	2.500	2.121
smf10sp2	1	5	5.500	0.707	6	5	5.667	0.577	6	1	1.667	1.155
smf11sp1	3	3	4.278	0.575	5	4	5.556	0.705	6	2	3.778	0.548
smf11sp2	3	6	6.000	NA	6	6	6.000	NA	6	3	3.000	NA

space	O7Max	O8Min	O8Mean	O8StdDev	O8Max	O9Min	O9Mean	O9StdDev	O9Max	O10Min	O10Mean	O10StdDev
nyc01sp1	3	7	8.462	0.776	9	1	7.643	2.240	9	1	6.000	3.258
nyc01sp2	3	7	7.333	0.577	8	6	7.000	1.000	8	1	2.333	1.155
nyc02sp1	4	5	7.375	1.506	9	4	6.750	1.488	9	3	6.125	2.031
nyc02sp2	2	4	6.364	1.649	9	2	6.091	2.158	9	2	4.714	1.384
nyc04sp1	4	5	7.429	1.512	9	3	7.143	2.268	9	2	6.143	3.024
nyc04sp2	4	4	7.167	1.528	9	4	6.833	1.586	9	2	5.583	2.575
nyc05sp1	3	1	5.333	2.251	7	4	6.000	1.414	8	1	4.000	2.000
nyc05sp2	4	5	6.200	1.304	8	5	6.000	1.225	8	2	4.000	1.871
nyc08sp1	4	5	7.000	2.828	9	5	7.000	2.828	9	4	5.000	1.414
nyc08sp2	4	7	8.333	1.155	9	9	9.000	0.000	9	2	3.000	1.414
nyc09sp1	4	7	7.833	0.983	9	4	7.167	1.835	9	3	4.167	1.169
sea01sp1	4	5	7.750	1.389	9	5	6.500	1.309	9	5	7.125	1.246
sea01sp2	4	5	7.714	1.380	9	3	7.143	2.035	9	4	6.286	1.496
sea01sp3	4	5	7.714	1.254	9	5	7.000	1.155	8	2	3.857	1.215
sea02sp1	4	9	9.000	NA	9	9	9.000	NA	9	5	5.000	NA
sea02sp2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea02sp3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea03sp1	2	1	5.333	2.503	8	1	4.000	1.673	6	4	5.000	1.095
sea03sp2	3	4	7.368	1.499	9	4	6.737	1.240	9	4	7.222	1.478
sea04sp1	3	7	7.667	0.577	8	6	7.333	1.155	8	6	6.667	0.577
sea04sp2	1	6	6.500	0.707	7	6	6.500	0.707	7	6	6.500	0.707
sea06sp1	4	6	7.250	0.957	8	5	7.000	1.633	9	3	6.000	2.449
sea06sp2	4	3	6.571	1.988	9	5	6.571	1.512	9	4	7.000	1.826
sea06sp3	2	8	8.667	0.577	9	8	8.667	0.577	9	5	6.000	1.732
sea06sp4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea07sp1	4	7	8.125	0.991	9	7	7.875	0.641	9	1	5.250	2.252
sea07sp2	3	7	7.667	0.577	8	6	7.333	1.155	8	1	3.667	2.309
sea07sp3	4	5	7.500	1.643	9	5	7.333	1.862	9	2	5.833	2.714
sfo01sp1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sfo01sp2	4	1	8.600	1.789	9	1	8.600	1.789	9	1	6.045	3.836
sfo01sp4	3	1	7.421	2.589	9	2	6.158	2.363	9	1	6.421	2.854
sfo02sp1	4	6	8.429	0.959	9	4	7.571	1.687	9	3	7.786	1.524
sfo02sp3	4	4	7.276	1.601	9	1	6.037	2.066	9	4	6.857	1.900
sfo04sp1	4	5	7.167	1.642	9	5	6.750	1.603	9	3	6.083	1.782
sfo04sp2	4	5	7.333	1.371	9	4	6.667	1.875	9	1	6.167	2.209
sfo05sp1	4	5	8.000	1.732	9	4	8.000	2.236	9	1	5.200	2.950
sfo05sp2	4	5	6.000	1.000	7	4	5.667	1.528	7	2	3.750	1.500
sfo05sp3	1	6	7.000	1.414	8	7	7.500	0.707	8	7	7.500	0.707
sfo05sp4	4	5	7.400	1.517	9	5	6.800	1.789	9	1	5.600	2.966
sfo06sp1	4	3	6.500	1.927	8	2	6.500	2.268	9	1	5.000	3.117
sfo06sp2	2	6	7.875	1.246	9	4	7.625	1.768	9	1	3.500	2.563
sfo07sp1	4	7	7.714	0.756	9	7	7.714	0.756	9	3	5.286	1.254
smf02sp1	4	5	7.333	1.303	9	2	6.308	2.428	9	1	3.231	1.739
smf03sp1	4	5	8.800	0.894	9	5	8.000	1.777	9	1	6.050	3.332
smf03sp2	4	1	7.200	2.058	9	1	6.069	2.698	9	1	6.897	2.335
smf04sp1	4	5	6.833	1.472	9	4	6.000	1.414	8	1	3.333	2.251
smf04sp2	4	3	7.000	2.138	9	4	6.500	2.000	9	3	6.875	2.232
smf04sp3	4	5	7.818	1.471	9	4	6.833	1.528	9	1	5.917	2.193
smf05sp1	4	3	6.250	2.053	8	3	5.625	2.387	9	2	6.000	2.390
smf06sp1	4	4	6.125	1.258	9	1	4.294	2.085	9	1	5.529	2.741
smf06sp2	4	5	8.000	1.664	9	1	5.571	2.928	9	1	7.615	2.293
smf06sp3	2	1	4.833	2.259	9	1	3.958	2.274	9	3	6.560	1.685
smf07sp1	4	5	7.600	1.506	9	5	7.400	1.506	9	4	7.400	1.506
smf08sp1	4	4	7.833	1.249	9	4	7.056	1.392	9	3	6.111	2.298
smf08sp2	3	5	7.167	1.835	9	5	7.167	1.602	9	5	7.333	1.633
smf08sp3	4	1	7.143	1.533	9	3	6.500	1.895	9	1	5.786	2.331
smf09sp1	1	1	3.400	1.955	6	5	7.400	1.075	9	2	6.111	2.713
smf10sp1	4	6	7.500	2.121	9	8	8.500	0.707	9	2	5.000	4.243
smf10sp2	3	5	5.000	0.000	5	3	5.000	2.000	7	1	1.333	0.577
smf11sp1	4	5	7.833	0.985	9	5	7.278	1.127	9	1	4.667	1.910
smf11sp2	3	6	6.000	NA	6	6	6.000	NA	6	6	6.000	NA

space	O10Max	O11Min	O11Mean	O11StdDev	O11Max	O12Min	O12Mean	O12StdDev	O12Max	O13Min	O13Mean	O13StdDev
nyc01sp1	9	1	7.214	2.424	9	5	8.545	1.214	9	7	8.692	0.630
nyc01sp2	3	5	6.000	1.732	8	1	3.000	2.000	5	1	3.667	3.786
nyc02sp1	9	3	5.875	2.357	9	5	6.500	1.604	9	4	7.500	2.000
nyc02sp2	7	3	5.682	1.644	9	2	4.714	1.586	8	2	5.381	2.012
nyc04sp1	9	7	7.857	0.690	9	4	7.714	1.799	9	7	8.286	0.756
nyc04sp2	9	1	5.583	2.429	8	5	6.909	1.758	9	5	7.833	1.467
nyc05sp1	6	5	6.500	1.225	8	1	4.200	2.280	7	1	5.167	2.229
nyc05sp2	7	4	5.000	0.707	6	5	5.000	0.000	5	5	5.400	0.894
nyc08sp1	6	5	7.000	2.828	9	4	6.500	3.536	9	5	5.500	0.707
nyc08sp2	4	4	5.667	1.528	7	5	7.333	2.082	9	7	8.000	1.000
nyc09sp1	6	1	4.333	2.338	8	8	8.667	0.516	9	8	8.833	0.408
sea01sp1	9	2	5.875	2.100	8	3	6.500	2.330	9	5	7.250	1.389
sea01sp2	8	5	7.000	1.549	9	3	7.571	2.225	9	7	8.143	0.900
sea01sp3	6	4	5.857	1.345	8	5	7.286	1.704	9	7	8.143	0.900
sea02sp1	5	5	5.000	NA	5	6	6.000	NA	6	9	9.000	NA
sea02sp2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea02sp3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea03sp1	7	2	5.000	1.897	7	4	7.000	2.098	9	4	7.167	2.229
sea03sp2	9	2	5.632	1.950	8	4	5.917	2.021	9	3	6.091	2.166
sea04sp1	7	3	5.000	2.646	8	5	5.667	1.155	7	7	7.333	0.577
sea04sp2	7	7	7.000	0.000	7	8	8.000	0.000	8	8	8.000	0.000
sea06sp1	9	4	4.500	1.000	6	9	9.000	0.000	9	9	9.000	0.000
sea06sp2	9	2	5.714	2.215	8	1	7.571	2.936	9	8	8.667	0.516
sea06sp3	8	7	7.667	1.155	9	8	8.667	0.577	9	9	9.000	0.000
sea06sp4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea07sp1	8	1	6.000	2.449	9	8	8.875	0.354	9	8	8.750	0.463
sea07sp2	5	5	5.333	0.577	6	6	7.000	1.000	8	6	7.333	1.155
sea07sp3	9	1	4.000	2.000	6	6	8.333	1.211	9	5	8.167	1.602
sfo01sp1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sfo01sp2	9	5	6.500	2.121	8	1	3.864	3.733	9	7	8.000	1.414
sfo01sp4	9	1	4.579	2.610	9	1	7.000	2.887	9	1	6.895	2.601
sfo02sp1	9	1	6.643	1.909	9	1	7.286	2.258	9	2	7.036	2.236
sfo02sp3	9	1	6.586	2.196	9	1	6.207	2.858	9	2	7.000	2.148
sfo04sp1	9	3	5.583	1.505	8	4	7.333	1.826	9	6	8.083	1.084
sfo04sp2	9	1	5.500	2.067	8	4	7.000	1.265	9	4	7.750	1.422
sfo05sp1	9	2	5.200	3.114	9	5	7.333	2.082	9	6	7.333	1.155
sfo05sp2	5	3	6.500	2.646	9	5	5.667	1.155	7	3	5.000	2.828
sfo05sp3	8	1	4.500	4.950	8	6	6.000	NA	6	6	6.000	NA
sfo05sp4	9	5	6.400	1.673	9	2	5.750	2.872	8	2	5.750	2.872
sfo06sp1	8	4	6.125	1.458	8	1	4.400	3.286	8	1	4.600	3.507
sfo06sp2	9	1	3.286	1.976	6	2	5.800	2.490	8	1	5.600	3.130
sfo07sp1	7	3	6.000	1.633	8	4	6.667	1.751	8	5	7.714	1.380
smf02sp1	7	4	5.923	1.320	8	5	8.167	1.115	9	6	8.364	1.027
smf03sp1	9	1	7.500	2.819	9	1	7.737	2.684	9	1	5.400	3.152
smf03sp2	9	1	4.933	1.760	8	1	7.000	2.289	9	1	7.700	2.020
smf04sp1	6	1	4.000	1.897	6	4	6.667	1.751	9	5	6.833	1.472
smf04sp2	9	1	5.000	2.563	9	3	6.429	2.299	9	1	6.429	3.409
smf04sp3	8	1	6.250	2.179	8	4	7.300	1.418	9	5	7.909	1.578
smf05sp1	9	5	6.625	1.061	8	1	3.833	2.401	7	1	4.000	2.966
smf06sp1	9	1	6.176	2.099	9	1	3.647	2.499	9	1	5.765	2.635
smf06sp2	9	1	5.214	3.262	9	1	5.000	3.088	9	1	4.857	3.592
smf06sp3	9	4	6.920	1.525	9	1	2.870	2.029	7	1	4.087	3.044
smf07sp1	9	4	7.500	1.716	9	6	8.200	0.919	9	7	8.300	0.675
smf08sp1	9	3	6.333	2.058	9	2	7.176	2.270	9	1	7.412	2.293
smf08sp2	9	4	6.833	2.137	9	4	7.167	2.137	9	4	7.833	1.941
smf08sp3	9	1	5.929	2.193	9	1	7.464	2.099	9	4	8.071	1.359
smf09sp1	9	3	6.000	2.000	9	1	6.400	2.633	9	4	7.000	1.871
smf10sp1	8	5	6.500	2.121	8	9	9.000	0.000	9	8	8.500	0.707
smf10sp2	2	4	6.000	2.646	9	4	6.000	2.646	9	5	7.000	2.828
smf11sp1	9	1	5.556	2.281	9	3	6.667	1.815	9	6	8.056	0.873
smf11sp2	6	8	8.000	NA	8	8	8.000	NA	8	8	8.000	NA

space	O13Max	O14Min	O14Mean	O14StdDev	O14Max	O15Min	O15Mean	O15StdDev	O15Max	O16Min	O16Mean	O16StdDev
nyc01sp1	9	1	6.000	4.359	9	1	6.923	2.871	9	1	6.231	3.370
nyc01sp2	8	8	8.500	0.707	9	2	4.000	3.464	8	1	4.000	4.359
nyc02sp1	9	5	6.875	1.808	9	1	4.875	2.232	8	4	8.000	1.690
nyc02sp2	8	2	5.500	1.921	8	4	6.318	1.492	9	4	6.818	1.763
nyc04sp1	9	5	7.429	1.272	9	5	7.286	1.380	9	7	8.143	0.690
nyc04sp2	9	1	4.917	2.778	9	2	6.250	2.301	9	3	6.833	2.082
nyc05sp1	7	1	3.667	2.422	7	1	3.833	2.229	7	1	4.000	2.280
nyc05sp2	7	1	2.400	1.342	4	1	3.000	2.000	5	1	4.200	1.924
nyc08sp1	6	5	5.500	0.707	6	3	4.000	1.414	5	5	6.500	2.121
nyc08sp2	9	7	7.333	0.577	8	7	7.333	0.577	8	7	7.667	0.577
nyc09sp1	9	3	5.333	3.215	9	3	5.000	2.098	9	3	5.833	2.317
sea01sp1	9	2	6.286	2.498	9	2	6.250	2.188	9	4	6.750	1.669
sea01sp2	9	3	5.714	1.976	9	6	7.000	0.816	8	6	7.143	1.069
sea01sp3	9	3	5.857	1.952	9	5	6.429	0.976	8	4	6.286	1.799
sea02sp1	9	7	7.000	NA	7	5	5.000	NA	5	9	9.000	NA
sea02sp2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea02sp3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea03sp1	9	4	5.167	1.169	7	2	3.833	1.169	5	5	5.333	0.816
sea03sp2	9	2	5.000	2.121	7	1	6.737	1.996	9	2	6.647	1.998
sea04sp1	8	3	3.000	NA	3	8	8.000	0.000	8	3	5.667	2.517
sea04sp2	8	7	7.000	0.000	7	7	7.500	0.707	8	7	7.500	0.707
sea06sp1	9	7	8.500	1.000	9	3	5.500	1.915	7	4	6.250	1.708
sea06sp2	9	6	7.286	0.756	8	3	6.000	2.000	8	3	6.714	1.976
sea06sp3	9	5	7.333	2.082	9	4	6.000	1.732	7	8	8.667	0.577
sea06sp4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea07sp1	9	7	8.250	0.886	9	7	8.250	0.886	9	7	8.375	0.744
sea07sp2	8	5	5.667	1.155	7	5	6.000	1.732	8	5	6.667	1.528
sea07sp3	9	5	5.000	NA	5	6	7.833	1.169	9	7	7.500	0.837
sfo01sp1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sfo01sp2	9	6	7.500	2.121	9	6	6.500	0.707	7	6	7.500	2.121
sfo01sp4	9	1	6.158	2.566	9	1	5.474	3.533	9	1	6.105	2.767
sfo02sp1	9	3	7.607	1.618	9	5	8.444	1.121	9	5	8.000	1.414
sfo02sp3	9	1	6.370	2.290	9	2	6.897	2.381	9	2	7.167	2.140
sfo04sp1	9	1	7.167	2.250	9	3	6.583	1.929	9	1	6.250	2.221
sfo04sp2	9	6	7.909	1.044	9	3	7.333	1.670	9	2	6.750	2.454
sfo05sp1	8	6	7.333	1.528	9	4	7.600	2.191	9	6	8.200	1.304
sfo05sp2	7	1	1.000	NA	1	1	2.750	1.500	4	1	3.000	1.633
sfo05sp3	6	Inf	NA	NA	#NAME?	2	5.000	4.243	8	7	8.000	1.414
sfo05sp4	8	5	7.000	1.732	8	3	5.600	1.817	8	5	6.200	1.643
sfo06sp1	8	1	2.250	2.500	6	1	5.250	2.435	8	3	5.571	1.902
sfo06sp2	9	9	9.000	NA	9	3	6.250	2.375	9	3	6.000	2.000
sfo07sp1	9	5	7.000	1.414	8	5	6.857	1.574	9	5	7.429	1.397
smf02sp1	9	1	1.000	NA	1	4	6.273	1.555	9	3	6.923	1.754
smf03sp1	9	1	1.000	NA	1	1	5.632	3.593	9	1	5.632	3.059
smf03sp2	9	2	6.655	2.424	9	2	7.367	2.141	9	1	7.000	2.464
smf04sp1	9	5	6.833	1.472	9	3	6.333	2.422	9	4	6.333	1.862
smf04sp2	9	5	7.167	1.602	9	3	7.000	2.330	9	4	7.875	1.727
smf04sp3	9	1	5.900	2.644	9	3	6.250	2.050	9	2	5.750	2.301
smf05sp1	8	3	3.000	NA	3	5	7.250	1.165	9	5	7.250	1.669
smf06sp1	9	1	4.563	2.898	9	2	7.000	2.098	9	3	6.938	2.112
smf06sp2	9	3	8.500	1.605	9	3	7.714	1.978	9	1	6.500	2.955
smf06sp3	9	1	4.130	2.546	8	1	5.680	2.116	9	3	6.417	1.717
smf07sp1	9	5	8.000	1.549	9	4	7.900	1.595	9	4	7.500	1.650
smf08sp1	9	4	7.222	1.629	9	5	7.556	1.423	9	1	7.056	2.014
smf08sp2	9	5	7.167	1.835	9	4	7.333	1.966	9	6	7.833	1.169
smf08sp3	9	4	7.643	1.569	9	2	7.071	1.980	9	4	7.407	1.551
smf09sp1	9	1	6.333	3.445	9	3	6.556	2.128	9	4	6.571	1.902
smf10sp1	9	Inf	NA	NA	#NAME?	9	9.000	0.000	9	8	8.500	0.707
smf10sp2	9	9	9.000	NA	9	2	3.333	1.528	5	2	3.333	1.528
smf11sp1	9	1	7.111	2.083	9	3	7.111	1.530	9	4	7.389	1.614
smf11sp2	8	Inf	NA	NA	#NAME?	3	3.000	NA	3	3	3.000	NA

space	O16Max	O17Min	O17Mean	O17StdDev	O17Max	O18Min	O18Mean	O18StdDev	O18Max	O19Min	O19Mean	O19StdDev
nyc01sp1	9	7	8.538	0.776	9	1	6.000	3.542	9	1	4.182	2.926
nyc01sp2	9	4	7.333	2.887	9	1	1.333	0.577	2	1	1.000	0.000
nyc02sp1	9	5	7.250	1.389	9	5	7.143	1.345	9	3	4.857	2.035
nyc02sp2	9	4	7.091	1.509	9	4	6.636	1.761	9	1	5.000	2.309
nyc04sp1	9	6	8.429	1.134	9	5	7.286	1.704	9	5	7.333	1.862
nyc04sp2	9	2	7.417	1.929	9	4	7.083	1.443	9	1	4.909	2.548
nyc05sp1	7	1	4.333	2.338	7	5	6.000	1.732	9	2	4.800	2.588
nyc05sp2	6	1	5.000	2.550	8	1	3.200	1.483	5	1	1.600	1.342
nyc08sp1	8	5	5.000	0.000	5	3	3.500	0.707	4	3	3.500	0.707
nyc08sp2	8	7	7.667	0.577	8	2	4.000	1.732	5	1	2.000	1.000
nyc09sp1	9	3	6.833	2.401	9	5	7.167	1.472	9	1	4.833	2.994
sea01sp1	9	2	5.500	2.976	9	5	7.625	1.302	9	1	5.750	2.605
sea01sp2	9	3	7.000	2.082	9	7	7.714	0.488	8	3	5.286	2.289
sea01sp3	9	2	6.286	2.498	9	4	6.857	1.574	9	1	4.429	2.878
sea02sp1	9	9	9.000	NA	9	9	9.000	NA	9	5	5.000	NA
sea02sp2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea02sp3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea03sp1	7	3	6.200	2.168	8	6	7.400	1.140	9	6	7.333	1.211
sea03sp2	9	1	7.313	2.330	9	6	8.000	1.085	9	3	7.765	1.751
sea04sp1	8	6	7.000	1.000	8	7	7.667	0.577	8	8	8.500	0.707
sea04sp2	8	8	8.000	0.000	8	6	7.000	1.414	8	6	7.000	1.414
sea06sp1	8	2	5.750	3.304	9	7	8.250	0.957	9	6	7.000	1.155
sea06sp2	8	5	7.286	1.113	8	3	6.429	2.070	9	1	3.143	2.911
sea06sp3	9	9	9.000	0.000	9	8	8.667	0.577	9	6	7.000	1.000
sea06sp4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea07sp1	9	8	8.500	0.535	9	6	7.750	1.165	9	1	5.125	3.044
sea07sp2	8	5	6.667	1.528	8	4	6.000	2.000	8	2	4.333	2.082
sea07sp3	9	7	8.000	0.894	9	7	7.667	0.816	9	6	7.500	1.291
sfo01sp1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sfo01sp2	9	4	5.500	2.121	7	7	8.000	1.414	9	1	7.364	3.140
sfo01sp4	9	1	6.105	3.230	9	1	6.684	3.284	9	1	6.263	3.445
sfo02sp1	9	3	7.889	1.601	9	4	7.963	1.531	9	4	8.037	1.344
sfo02sp3	9	1	7.000	2.480	9	1	7.276	2.016	9	1	5.370	2.989
sfo04sp1	9	1	7.000	2.663	9	1	6.333	2.774	9	1	5.583	2.999
sfo04sp2	9	2	7.083	2.275	9	3	7.250	1.765	9	2	5.667	2.103
sfo05sp1	9	3	6.800	3.033	9	1	6.200	3.114	9	1	2.400	0.894
sfo05sp2	5	2	5.250	2.872	9	1	3.750	2.062	6	1	3.750	2.754
sfo05sp3	9	4	6.500	3.536	9	5	6.500	2.121	8	2	2.500	0.707
sfo05sp4	9	5	7.000	1.871	9	5	7.000	1.871	9	1	3.600	3.130
sfo06sp1	8	4	7.375	1.923	9	1	6.000	3.225	9	1	4.125	3.399
sfo06sp2	9	5	8.000	1.414	9	1	4.857	3.671	9	1	4.286	3.200
sfo07sp1	9	1	5.571	2.370	8	6	6.857	0.690	8	1	4.429	2.225
smf02sp1	9	5	6.692	1.316	9	1	5.385	2.399	9	1	2.154	2.075
smf03sp1	9	3	3.000	NA	3	9	9.000	0.000	9	1	7.150	3.345
smf03sp2	9	1	7.033	2.798	9	1	7.310	2.436	9	1	6.933	2.449
smf04sp1	9	3	6.500	2.588	9	4	7.500	2.345	9	4	7.000	2.366
smf04sp2	9	3	7.375	2.504	9	6	8.375	1.188	9	1	5.125	3.907
smf04sp3	9	6	7.667	1.073	9	1	5.750	2.563	9	1	3.364	2.157
smf05sp1	9	5	8.000	1.414	9	5	7.875	1.458	9	6	7.750	1.389
smf06sp1	9	5	7.824	1.380	9	1	6.118	2.619	9	1	5.059	3.030
smf06sp2	9	1	6.214	3.118	9	1	7.571	2.533	9	1	6.857	3.085
smf06sp3	9	1	6.208	2.322	9	2	6.680	1.819	9	1	5.826	2.424
smf07sp1	9	4	7.700	1.703	9	3	7.700	1.947	9	1	6.500	2.677
smf08sp1	9	5	7.294	1.611	9	6	7.889	1.079	9	3	7.222	1.700
smf08sp2	9	8	8.667	0.516	9	5	7.833	1.835	9	4	6.667	1.966
smf08sp3	9	1	6.667	2.542	9	4	8.071	1.386	9	1	7.250	2.171
smf09sp1	9	4	6.625	1.598	9	1	4.429	2.760	9	1	4.125	3.137
smf10sp1	9	6	6.500	0.707	7	5	7.000	2.828	9	8	8.500	0.707
smf10sp2	5	5	7.667	2.309	9	1	2.333	2.309	5	1	2.333	2.309
smf11sp1	9	2	7.278	1.841	9	7	8.111	0.900	9	1	6.778	2.157
smf11sp2	3	6	6.000	NA	6	6	6.000	NA	6	6	6.000	NA

space	O19Max	O20Min	O20Mean	O20StdDev	O20Max	O21Min	O21Mean	O21StdDev	O21Max	O22Min	O22Mean	O22StdDev
nyc01sp1	9	1	5.923	3.013	9	3	7.714	1.684	9	1	7.167	2.657
nyc01sp2	1	1	1.333	0.577	2	4	5.667	1.528	7	1	6.000	4.359
nyc02sp1	9	3	6.125	2.100	9	1	4.125	2.357	8	1	4.375	2.264
nyc02sp2	9	1	4.773	1.716	9	4	6.682	1.427	9	4	7.045	1.527
nyc04sp1	9	7	8.286	0.756	9	2	6.714	2.430	9	2	6.429	2.507
nyc04sp2	8	1	5.083	2.778	9	2	5.250	2.491	9	2	6.333	2.270
nyc05sp1	9	4	5.333	1.366	7	1	3.500	3.209	8	1	3.667	2.805
nyc05sp2	4	1	3.800	1.789	5	1	3.000	2.000	6	1	2.400	1.517
nyc08sp1	4	5	6.500	2.121	8	3	4.000	1.414	5	5	6.500	2.121
nyc08sp2	3	2	6.333	3.786	9	2	5.000	2.646	7	7	7.333	0.577
nyc09sp1	9	2	4.833	2.927	9	2	4.500	2.881	9	2	4.167	3.061
sea01sp1	9	3	6.500	2.268	9	5	6.875	1.356	9	2	6.000	3.162
sea01sp2	8	3	5.714	2.289	8	3	6.286	2.215	9	3	6.000	2.082
sea01sp3	9	3	5.000	1.633	8	5	7.429	1.618	9	4	6.857	1.676
sea02sp1	5	8	8.000	NA	8	4	4.000	NA	4	1	1.000	NA
sea02sp2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea02sp3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea03sp1	9	5	6.333	1.211	8	2	3.167	1.941	7	2	3.667	2.251
sea03sp2	9	3	7.789	1.619	9	3	7.500	1.757	9	3	7.684	1.565
sea04sp1	9	5	7.000	2.000	9	3	5.000	2.646	8	4	6.000	1.732
sea04sp2	8	6	7.000	1.414	8	6	7.000	1.414	8	7	7.500	0.707
sea06sp1	8	3	6.250	2.217	8	1	6.250	3.594	9	1	5.750	3.202
sea06sp2	8	1	5.714	2.690	8	1	2.857	1.773	6	1	3.714	2.690
sea06sp3	8	8	8.333	0.577	9	1	3.333	2.082	5	3	5.000	2.000
sea06sp4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sea07sp1	9	6	8.000	1.195	9	1	5.500	2.726	9	1	4.625	2.066
sea07sp2	6	5	5.667	0.577	6	2	3.667	1.528	5	2	3.333	1.528
sea07sp3	9	4	6.667	2.066	9	5	8.000	1.549	9	6	8.167	1.169
sfo01sp1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
sfo01sp2	9	5	6.000	1.414	7	6	6.500	0.707	7	3	6.000	4.243
sfo01sp4	9	1	6.158	2.794	9	1	5.474	3.238	9	1	5.158	3.610
sfo02sp1	9	4	7.885	1.583	9	1	7.778	2.276	9	2	7.778	1.649
sfo02sp3	9	1	5.852	2.656	9	1	6.286	2.651	9	1	5.103	2.968
sfo04sp1	9	1	6.250	2.491	9	2	5.417	2.678	9	1	6.000	2.449
sfo04sp2	8	4	6.333	1.723	9	2	5.417	2.109	8	3	5.917	2.065
sfo05sp1	3	1	5.800	3.633	9	6	8.250	1.500	9	1	6.400	3.209
sfo05sp2	7	1	2.000	1.155	3	3	6.250	3.202	9	5	7.250	1.708
sfo05sp3	3	3	5.500	3.536	8	6	7.500	2.121	9	7	8.000	1.414
sfo05sp4	9	1	5.600	3.578	9	5	5.500	0.577	6	5	6.400	1.517
sfo06sp1	9	1	4.429	2.573	7	7	8.143	0.900	9	1	6.429	2.637
sfo06sp2	8	5	6.625	1.598	9	5	7.750	1.389	9	3	6.875	2.532
sfo07sp1	7	3	6.143	1.864	9	3	6.857	1.952	9	5	6.857	1.464
smf02sp1	8	2	5.667	1.875	9	5	7.333	1.303	9	6	7.538	1.127
smf03sp1	9	1	4.611	3.550	9	1	3.850	3.167	9	9	9.000	NA
smf03sp2	9	5	7.185	1.520	9	2	7.517	1.939	9	6	8.233	1.165
smf04sp1	9	4	7.000	1.789	9	6	7.800	1.095	9	4	6.167	1.602
smf04sp2	9	1	5.625	3.462	9	2	7.375	2.615	9	2	7.750	2.375
smf04sp3	7	3	5.750	1.712	8	3	7.000	2.335	9	3	7.333	2.015
smf05sp1	9	3	6.000	2.070	9	8	8.750	0.463	9	7	8.500	0.756
smf06sp1	9	1	4.294	2.995	9	1	6.706	2.640	9	5	7.882	1.409
smf06sp2	9	5	7.643	1.646	9	1	7.214	2.665	9	1	7.000	2.512
smf06sp3	9	1	4.200	2.309	9	3	7.571	1.720	9	3	7.440	1.781
smf07sp1	9	4	7.300	1.829	9	6	8.111	0.928	9	5	8.000	1.225
smf08sp1	9	5	7.389	1.195	9	3	7.056	1.392	9	7	8.111	0.832
smf08sp2	9	6	7.167	1.472	9	6	7.500	1.378	9	4	6.000	1.673
smf08sp3	9	3	6.464	1.453	9	1	6.750	2.489	9	1	7.500	1.934
smf09sp1	9	3	6.100	1.853	9	5	6.778	1.481	9	3	6.000	2.619
smf10sp1	9	5	6.000	1.414	7	7	8.000	1.414	9	8	8.500	0.707
smf10sp2	5	1	2.333	2.309	5	5	7.000	2.000	9	5	6.333	2.309
smf11sp1	9	4	7.500	1.425	9	2	7.222	2.130	9	3	7.611	1.501
smf11sp2	6	4	4.000	NA	4	6	6.000	NA	6	6	6.000	NA

space	O22Max	N.Expert	E1Min	E1Mean	E1StdDev	E1Max	E2Min	E2Mean	E2StdDev	E2Max	E3Min	E3Mean
nyc01sp1	9	6	6	7.500	1.049	9	6	7.333	1.033	9	3	5.667
nyc01sp2	9	6	3	5.333	1.633	7	3	5.000	1.414	7	5	6.167
nyc02sp1	7	7	6	6.857	0.690	8	5	7.000	1.000	8	3	4.286
nyc02sp2	9	7	6	7.000	0.816	8	5	7.000	1.155	8	3	4.571
nyc04sp1	9	7	6	7.000	0.577	8	6	6.857	0.690	8	3	6.286
nyc04sp2	9	7	6	6.571	0.535	7	5	6.571	0.976	8	3	5.714
nyc05sp1	8	7	4	6.857	1.676	9	4	6.429	1.397	8	3	5.571
nyc05sp2	4	7	4	5.857	1.345	7	3	6.000	1.633	8	3	4.857
nyc08sp1	8	6	3	4.333	1.966	8	3	4.333	1.366	7	3	5.000
nyc08sp2	8	2	4	5.000	1.414	6	3	4.500	2.121	6	6	6.500
nyc09sp1	9	4	7	7.750	0.500	8	7	7.750	0.500	8	5	5.500
sea01sp1	9	7	4	6.286	1.380	8	4	6.143	1.345	8	4	5.500
sea01sp2	9	7	5	6.429	1.272	8	5	6.429	1.272	8	3	5.333
sea01sp3	8	7	5	7.143	1.069	8	6	7.286	0.756	8	4	6.000
sea02sp1	1	7	7	8.000	0.577	9	7	8.000	0.577	9	4	6.500
sea02sp2	NA	7	3	4.286	0.756	5	3	4.143	1.215	6	5	6.333
sea02sp3	NA	7	6	6.571	0.787	8	6	6.429	0.787	8	4	5.667
sea03sp1	7	7	3	5.714	1.704	7	2	4.571	1.512	6	2	3.833
sea03sp2	9	7	2	7.000	2.380	9	3	7.000	1.915	9	4	5.333
sea04sp1	7	6	5	6.500	1.049	8	4	6.167	1.472	8	3	5.600
sea04sp2	8	6	7	7.500	0.548	8	6	7.333	0.816	8	4	6.200
sea06sp1	8	6	6	7.333	1.033	8	7	7.667	0.516	8	6	7.000
sea06sp2	8	6	7	7.833	0.753	9	7	7.833	0.753	9	6	7.200
sea06sp3	7	6	8	8.667	0.516	9	8	8.667	0.516	9	3	4.200
sea06sp4	NA	5	2	4.600	1.673	6	2	4.800	2.387	8	5	6.250
sea07sp1	7	6	4	5.833	1.602	8	4	5.833	1.835	8	5	5.600
sea07sp2	5	6	3	5.667	1.751	8	4	6.333	1.506	8	2	5.200
sea07sp3	9	6	7	7.833	0.408	8	7	8.000	0.894	9	6	7.000
sfo01sp1	NA	3	5	5.000	0.000	5	5	5.333	0.577	6	5	6.000
sfo01sp2	9	3	5	5.667	0.577	6	5	5.333	0.577	6	4	4.667
sfo01sp4	9	3	6	6.667	0.577	7	6	6.667	0.577	7	4	5.667
sfo02sp1	9	4	3	4.500	1.732	7	3	3.000	0.000	3	3	3.500
sfo02sp3	9	4	3	3.500	1.000	5	2	2.250	0.500	3	3	3.750
sfo04sp1	9	4	7	7.250	0.500	8	7	7.500	0.577	8	7	7.000
sfo04sp2	9	4	5	5.750	0.957	7	5	5.750	0.957	7	5	6.333
sfo05sp1	9	5	2	4.400	1.817	7	2	4.400	2.074	7	5	6.000
sfo05sp2	9	5	2	3.400	2.074	7	2	3.800	2.168	7	5	6.200
sfo05sp3	9	5	4	5.600	1.140	7	4	5.800	1.304	7	5	6.750
sfo05sp4	9	5	3	4.800	1.483	7	3	4.600	1.517	7	5	6.250
sfo06sp1	9	5	6	7.200	1.304	9	6	6.800	0.837	8	5	6.000
sfo06sp2	9	4	7	7.750	0.500	8	7	7.500	1.000	9	7	7.000
sfo07sp1	8	5	4	7.200	1.924	9	6	7.600	1.140	9	5	5.750
smf02sp1	9	5	3	4.800	1.483	7	3	4.200	2.168	8	3	5.000
smf03sp1	9	5	9	9.000	0.000	9	8	8.600	0.548	9	2	4.500
smf03sp2	9	5	7	8.200	0.837	9	7	8.200	0.837	9	2	5.000
smf04sp1	8	5	3	5.800	1.924	8	3	5.600	1.673	7	5	7.000
smf04sp2	9	5	4	6.200	1.483	8	4	6.200	1.483	8	5	7.250
smf04sp3	9	5	8	8.400	0.548	9	7	7.600	0.894	9	5	7.000
smf05sp1	9	4	6	7.250	1.500	9	4	6.500	2.380	9	5	7.000
smf06sp1	9	4	4	7.250	2.217	9	3	7.000	2.708	9	2	5.000
smf06sp2	9	4	8	8.500	0.577	9	7	8.000	0.816	9	7	7.000
smf06sp3	9	4	7	7.750	0.500	8	6	7.500	1.000	8	7	7.000
smf07sp1	9	4	6	6.750	0.500	7	6	7.250	0.957	8	4	6.250
smf08sp1	9	5	6	7.200	1.304	9	6	7.200	1.304	9	4	6.000
smf08sp2	9	5	3	6.200	1.924	8	4	6.000	1.581	8	6	6.667
smf08sp3	9	5	5	6.800	1.643	9	5	6.400	1.517	8	5	6.000
smf09sp1	9	5	3	5.200	1.483	7	2	5.000	2.121	7	3	4.000
smf10sp1	9	5	1	2.200	1.304	4	1	1.600	0.548	2	3	4.000
smf10sp2	9	5	1	1.200	0.447	2	1	1.200	0.447	2	3	4.000
smf11sp1	9	6	7	7.833	0.408	8	4	7.333	1.751	9	5	6.800
smf11sp2	6	4	7	7.250	0.500	8	7	7.500	0.577	8	7	7.333

space	E3StdDev	E3Max	E4Min	E4Mean	E4StdDev	E4Max	E5Min	E5Mean	E5StdDev	E5Max	E6Min	E6Mean
nyc01sp1	1.506	7	5	5.500	0.837	7	7	7.833	0.753	9	8	8.833
nyc01sp2	0.983	7	4	5.333	1.506	7	1	3.000	1.789	6	1	3.333
nyc02sp1	1.799	8	2	4.000	1.732	7	5	6.857	1.215	9	6	7.429
nyc02sp2	1.134	6	4	5.000	0.816	6	3	5.143	1.773	8	3	6.571
nyc04sp1	1.604	8	3	5.857	1.864	8	5	7.286	1.496	9	7	8.286
nyc04sp2	1.704	8	3	5.143	1.773	8	5	7.143	1.676	9	7	8.286
nyc05sp1	1.512	8	3	5.143	1.574	7	3	6.286	1.799	9	3	6.286
nyc05sp2	1.345	7	4	5.286	1.704	8	3	5.429	1.512	7	4	6.286
nyc08sp1	1.265	7	3	4.500	0.837	5	4	5.333	1.033	7	4	4.667
nyc08sp2	0.707	7	3	3.500	0.707	4	4	4.500	0.707	5	4	4.000
nyc09sp1	0.577	6	4	5.250	0.957	6	8	8.750	0.500	9	8	8.750
sea01sp1	1.378	7	3	4.333	1.033	5	3	6.286	1.890	8	4	7.714
sea01sp2	1.966	7	2	4.333	1.633	6	7	8.429	0.787	9	8	8.714
sea01sp3	1.581	8	4	5.833	1.472	8	6	7.857	1.069	9	8	8.571
sea02sp1	1.761	8	3	5.571	1.397	7	5	7.143	1.215	8	5	7.286
sea02sp2	1.033	8	5	6.333	1.211	8	3	6.000	1.826	8	1	4.429
sea02sp3	1.033	7	5	5.833	0.983	7	4	6.143	1.345	8	2	5.429
sea03sp1	1.472	6	3	4.667	1.506	7	4	6.571	1.397	8	8	8.429
sea03sp2	1.366	7	2	3.167	1.472	6	1	3.500	2.380	6	2	4.000
sea04sp1	2.074	8	1	3.833	2.137	6	3	5.333	2.066	8	3	4.667
sea04sp2	1.483	8	1	4.333	1.862	6	6	7.333	1.033	9	7	8.167
sea06sp1	1.000	8	5	6.400	1.673	9	4	7.667	2.160	9	5	7.667
sea06sp2	0.837	8	5	6.800	1.483	9	6	8.167	1.329	9	8	8.833
sea06sp3	1.304	6	4	6.600	1.673	8	9	9.000	0.000	9	9	9.000
sea06sp4	0.957	7	2	3.600	1.140	5	1	1.000	0.000	1	1	1.000
sea07sp1	0.548	6	4	4.800	0.837	6	5	7.667	1.506	9	5	7.667
sea07sp2	2.049	7	2	4.400	1.817	7	4	5.333	0.816	6	9	9.000
sea07sp3	1.000	8	5	5.000	0.000	5	7	8.167	0.753	9	6	8.333
sfo01sp1	1.414	7	3	3.000	0.000	3	2	2.000	0.000	2	1	1.667
sfo01sp2	0.577	5	2	3.000	1.000	4	4	4.667	0.577	5	7	7.667
sfo01sp4	1.528	7	3	5.000	1.732	6	5	6.000	1.000	7	7	7.667
sfo02sp1	0.577	4	4	4.500	0.577	5	2	3.250	1.258	5	3	3.750
sfo02sp3	0.957	5	1	3.500	1.915	5	1	2.250	1.258	4	1	3.000
sfo04sp1	0.000	7	2	4.000	1.826	6	7	7.500	0.577	8	8	8.500
sfo04sp2	1.155	7	3	4.000	1.414	6	5	6.750	1.708	9	7	7.750
sfo05sp1	1.414	8	4	5.400	1.517	8	3	3.600	0.894	5	2	3.400
sfo05sp2	1.304	8	3	4.800	1.095	6	1	1.800	0.837	3	1	2.600
sfo05sp3	1.258	8	5	6.200	1.643	8	4	4.400	0.548	5	5	6.400
sfo05sp4	0.957	7	4	5.400	1.140	7	3	3.800	0.447	4	2	3.200
sfo06sp1	0.816	7	3	4.600	1.342	6	2	5.000	2.160	7	1	4.800
sfo06sp2	0.000	7	2	3.750	1.258	5	1	1.000	NA	1	1	1.000
sfo07sp1	0.957	7	3	4.000	0.707	5	5	5.750	0.957	7	6	7.250
smf02sp1	2.160	8	5	6.000	1.732	8	4	6.400	1.949	9	2	4.200
smf03sp1	3.536	7	2	2.000	NA	2	7	8.200	0.837	9	9	9.000
smf03sp2	4.243	8	2	2.000	0.000	2	7	8.200	0.837	9	7	8.600
smf04sp1	1.414	8	1	4.000	1.871	6	2	4.000	1.581	6	2	5.000
smf04sp2	1.708	9	1	4.200	2.280	7	3	5.000	1.581	7	3	6.200
smf04sp3	1.414	8	5	6.400	1.517	8	4	4.600	0.548	5	3	5.750
smf05sp1	1.732	8	2	3.000	1.414	5	1	1.667	1.155	3	1	1.000
smf06sp1	3.000	8	3	5.000	2.000	7	7	8.000	0.816	9	7	8.250
smf06sp2	0.000	7	6	7.000	1.000	8	4	5.250	0.957	6	4	6.250
smf06sp3	0.000	7	6	6.667	0.577	7	6	7.000	0.816	8	8	8.250
smf07sp1	1.500	7	5	6.000	1.000	7	5	6.250	1.258	8	4	5.250
smf08sp1	1.732	7	5	6.000	1.732	8	6	7.600	1.140	9	6	8.000
smf08sp2	0.577	7	5	6.000	1.000	7	5	6.600	1.673	9	3	5.400
smf08sp3	1.000	7	5	5.333	0.577	6	7	7.800	0.837	9	6	7.400
smf09sp1	2.000	7	1	2.333	1.155	3	4	6.200	1.643	8	4	7.200
smf10sp1	1.000	5	5	5.000	0.000	5	2	3.200	1.095	4	1	1.400
smf10sp2	1.000	5	5	5.000	0.000	5	2	4.000	1.581	6	1	1.600
smf11sp1	1.095	8	4	4.500	0.577	5	5	7.200	1.483	9	8	8.500
smf11sp2	0.577	8	6	6.667	1.155	8	5	6.000	0.816	7	3	5.500

space	E6StdDev	E6Max	E7Min	E7Mean	E7StdDev	E7Max	E8Min	E8Mean	E8StdDev	E8Max	E9Min	E9Mean
nyc01sp1	0.408	9	Inf	NA	NA	#NAME?	4	6.500	1.643	8	5	5.800
nyc01sp2	2.066	7	5	6.000	0.894	7	3	5.000	1.414	7	4	6.000
nyc02sp1	0.976	9	6	7.286	0.951	9	3	5.286	1.604	7	5	7.333
nyc02sp2	1.813	9	6	7.571	1.134	9	5	6.429	1.134	8	3	6.714
nyc04sp1	0.951	9	4	6.000	1.732	9	2	4.857	1.773	7	6	7.286
nyc04sp2	0.756	9	3	5.571	1.902	9	3	4.857	1.464	7	6	7.429
nyc05sp1	2.138	9	4	5.857	1.773	8	3	5.143	1.345	7	4	6.143
nyc05sp2	1.799	9	2	4.500	1.871	7	2	4.429	1.902	7	5	6.429
nyc08sp1	0.516	5	3	3.833	0.753	5	4	5.500	1.643	8	5	6.333
nyc08sp2	0.000	4	4	4.000	0.000	4	7	7.500	0.707	8	7	7.500
nyc09sp1	0.500	9	Inf	NA	NA	#NAME?	7	7.250	0.500	8	7	7.250
sea01sp1	1.704	9	2	6.000	2.309	9	5	6.429	1.134	8	5	7.000
sea01sp2	0.488	9	4	6.857	1.676	8	3	4.857	1.574	7	4	7.143
sea01sp3	0.535	9	5	6.857	1.069	8	4	5.714	1.380	7	3	7.333
sea02sp1	1.604	9	5	6.000	0.816	7	2	5.571	1.902	8	6	7.286
sea02sp2	2.370	8	3	5.857	1.676	7	4	5.143	1.345	8	5	5.857
sea02sp3	2.440	8	1	4.857	2.340	7	3	5.143	1.464	7	2	5.857
sea03sp1	0.535	9	1	3.714	2.059	7	2	3.714	2.138	8	3	5.143
sea03sp2	1.826	6	1	2.333	2.309	5	2	5.571	2.760	8	1	4.714
sea04sp1	2.066	8	1	3.000	2.160	6	5	6.333	1.211	8	4	5.800
sea04sp2	0.753	9	6	7.167	0.753	8	5	7.000	1.265	9	6	7.500
sea06sp1	1.751	9	3	6.167	1.835	8	4	6.167	1.472	8	7	8.167
sea06sp2	0.408	9	3	6.167	1.835	8	5	7.000	1.095	8	7	8.000
sea06sp3	0.000	9	7	7.667	0.816	9	5	7.000	1.789	9	1	4.000
sea06sp4	0.000	1	1	1.000	NA	1	3	5.000	1.581	7	2	4.200
sea07sp1	2.066	9	5	7.167	1.722	9	4	6.167	1.722	8	4	6.833
sea07sp2	0.000	9	1	4.333	2.160	7	2	4.667	1.751	7	5	7.000
sea07sp3	1.211	9	Inf	NA	NA	#NAME?	6	7.667	1.033	9	6	7.500
sfo01sp1	0.577	2	1	1.000	NA	1	4	5.667	1.528	7	4	5.667
sfo01sp2	0.577	8	4	5.333	1.528	7	3	4.333	1.528	6	4	6.000
sfo01sp4	0.577	8	5	6.333	1.155	7	6	6.500	0.707	7	6	6.667
sfo02sp1	0.500	4	1	2.750	1.258	4	3	5.000	1.633	7	4	6.250
sfo02sp3	1.826	5	2	2.500	1.000	4	2	3.750	1.708	6	5	6.250
sfo04sp1	0.577	9	3	5.500	1.732	7	4	6.250	1.708	8	7	8.000
sfo04sp2	0.957	9	4	5.500	1.000	6	4	6.250	1.500	7	6	7.250
sfo05sp1	1.140	5	2	3.800	1.095	5	2	4.600	2.302	8	2	5.400
sfo05sp2	2.510	7	Inf	NA	NA	#NAME?	2	4.000	2.000	7	5	6.200
sfo05sp3	1.673	9	5	6.000	1.732	8	3	5.200	2.049	7	4	6.800
sfo05sp4	0.837	4	3	4.400	1.673	7	3	5.000	1.581	7	3	6.000
sfo06sp1	3.114	8	1	1.000	NA	1	4	5.800	1.304	7	4	5.800
sfo06sp2	NA	1	1	1.000	NA	1	2	5.750	2.500	7	7	8.000
sfo07sp1	1.500	9	2	4.400	1.817	7	3	5.400	2.074	8	4	5.600
smf02sp1	2.950	9	Inf	NA	NA	#NAME?	3	5.000	1.871	7	4	7.200
smf03sp1	0.000	9	3	6.200	2.280	9	3	7.200	2.490	9	8	8.600
smf03sp2	0.894	9	1	3.400	2.191	7	7	7.400	0.548	8	6	8.200
smf04sp1	2.646	9	4	6.600	2.302	9	4	6.200	1.643	8	7	8.000
smf04sp2	2.387	9	5	6.800	1.304	8	5	7.200	1.304	8	7	8.000
smf04sp3	2.754	9	6	7.000	1.000	8	7	8.200	0.837	9	7	8.000
smf05sp1	0.000	1	1	1.000	NA	1	6	7.000	0.816	8	5	6.000
smf06sp1	0.957	9	7	8.000	0.816	9	4	7.250	2.217	9	4	5.667
smf06sp2	2.062	9	5	7.000	2.309	9	7	7.750	0.500	8	8	8.000
smf06sp3	0.500	9	5	6.750	1.708	9	8	8.000	0.000	8	8	8.000
smf07sp1	1.893	8	Inf	NA	NA	#NAME?	3	5.250	2.217	8	5	7.000
smf08sp1	1.225	9	3	5.000	2.345	8	6	6.800	0.837	8	7	8.200
smf08sp2	2.074	8	3	5.600	2.074	8	6	6.600	0.548	7	7	8.000
smf08sp3	1.140	9	3	5.400	2.408	8	5	6.400	1.140	8	6	7.600
smf09sp1	1.924	9	1	1.200	0.447	2	2	4.600	2.608	8	5	5.500
smf10sp1	0.548	2	2	4.000	1.581	6	1	2.000	0.707	3	2	4.200
smf10sp2	0.548	2	1	1.667	1.155	3	1	3.600	3.209	9	4	5.400
smf11sp1	0.548	9	6	7.500	1.049	9	7	8.000	0.632	9	7	8.200
smf11sp2	2.082	8	Inf	NA	NA	#NAME?	5	7.000	1.633	9	3	6.667

space	E9StdDev	E9Max	E10Min	E10Mean	E10StdDev	E10Max	E11Min	E11Mean	E11StdDev	E11Max	E12Min	E12Mean
nyc01sp1	0.447	6	5	7.000	1.414	8	7	8.167	0.983	9	3	6.333
nyc01sp2	1.095	7	4	5.167	0.983	6	5	7.500	1.517	9	1	4.833
nyc02sp1	1.366	9	5	7.167	1.472	9	7	8.286	0.756	9	3	6.714
nyc02sp2	2.215	9	4	6.286	1.604	8	6	8.429	1.134	9	4	7.143
nyc04sp1	0.756	8	2	5.286	2.138	8	3	6.429	1.618	8	3	3.571
nyc04sp2	0.787	8	2	4.286	2.498	8	7	7.714	0.756	9	3	4.571
nyc05sp1	1.773	8	2	6.143	2.340	8	7	8.000	1.000	9	4	6.714
nyc05sp2	0.976	8	6	7.143	0.900	8	7	8.143	0.900	9	2	6.286
nyc08sp1	1.211	8	5	6.333	1.211	8	1	4.167	1.941	7	1	2.500
nyc08sp2	0.707	8	6	6.500	0.707	7	1	3.000	2.828	5	1	2.500
nyc09sp1	0.500	8	6	7.250	0.957	8	8	8.750	0.500	9	7	7.500
sea01sp1	1.414	9	7	8.143	0.900	9	7	8.000	0.816	9	4	6.429
sea01sp2	1.676	9	5	7.714	1.496	9	2	7.286	2.430	9	1	5.714
sea01sp3	2.251	9	6	8.000	1.095	9	7	8.429	0.787	9	2	7.286
sea02sp1	0.756	8	5	7.429	1.272	9	8	8.571	0.535	9	6	7.714
sea02sp2	1.069	7	5	6.857	1.574	9	2	4.857	1.676	7	1	2.286
sea02sp3	2.035	8	5	7.000	1.528	9	7	8.143	0.690	9	4	6.000
sea03sp1	2.340	9	3	5.143	1.952	8	5	8.000	1.528	9	5	7.000
sea03sp2	2.752	8	2	5.857	2.734	9	8	8.714	0.488	9	6	7.857
sea04sp1	1.304	7	3	4.800	2.049	7	8	8.667	0.516	9	7	7.667
sea04sp2	1.049	9	5	7.667	1.506	9	8	8.667	0.516	9	7	8.167
sea06sp1	0.753	9	7	8.667	0.816	9	6	7.000	1.095	9	2	3.833
sea06sp2	0.632	9	6	8.000	1.095	9	7	8.167	0.753	9	3	5.600
sea06sp3	2.449	7	1	4.833	3.371	9	9	9.000	0.000	9	7	8.667
sea06sp4	2.280	8	1	1.800	0.837	3	7	8.200	1.095	9	7	8.000
sea07sp1	1.722	9	7	8.167	0.983	9	7	8.167	0.983	9	1	4.833
sea07sp2	1.095	8	2	6.000	2.608	9	5	8.167	1.602	9	2	6.333
sea07sp3	1.378	9	6	8.167	1.169	9	7	8.667	0.816	9	6	8.000
sfo01sp1	1.528	7	6	7.000	1.000	8	6	7.000	1.000	8	3	3.333
sfo01sp2	1.732	7	7	7.333	0.577	8	8	8.333	0.577	9	5	5.667
sfo01sp4	1.155	8	6	7.000	1.000	8	8	8.667	0.577	9	6	6.667
sfo02sp1	1.500	7	4	7.000	2.160	9	7	7.750	0.957	9	3	5.250
sfo02sp3	1.500	8	5	5.250	0.500	6	3	4.000	1.414	6	2	2.500
sfo04sp1	0.816	9	7	7.500	0.577	8	9	9.000	0.000	9	4	6.000
sfo04sp2	0.957	8	6	7.750	1.258	9	8	8.250	0.500	9	2	4.750
sfo05sp1	2.074	7	3	6.200	2.280	9	3	4.200	1.643	7	1	2.600
sfo05sp2	1.095	7	3	6.200	2.168	8	2	3.600	2.074	7	1	1.200
sfo05sp3	1.924	9	3	6.000	2.345	8	3	6.800	2.280	9	1	4.400
sfo05sp4	2.000	8	3	6.000	2.121	8	4	5.400	1.517	8	1	3.400
sfo06sp1	1.789	8	7	7.800	0.837	9	8	8.800	0.447	9	7	8.200
sfo06sp2	1.414	9	7	8.000	1.155	9	8	8.750	0.500	9	7	7.750
sfo07sp1	1.517	7	3	5.400	2.408	8	8	8.400	0.548	9	7	7.600
smf02sp1	1.789	8	4	6.000	1.414	7	2	5.200	2.950	8	1	2.000
smf03sp1	0.548	9	5	7.600	1.673	9	9	9.000	0.000	9	8	8.800
smf03sp2	1.304	9	5	7.600	1.517	9	8	8.800	0.447	9	5	7.800
smf04sp1	1.000	9	7	8.000	1.000	9	7	8.200	0.837	9	3	5.000
smf04sp2	1.000	9	7	8.400	0.894	9	7	8.200	1.095	9	4	5.400
smf04sp3	0.707	9	8	8.600	0.548	9	9	9.000	0.000	9	8	8.400
smf05sp1	1.414	7	9	9.000	NA	9	8	8.750	0.500	9	7	8.500
smf06sp1	1.528	7	4	6.667	2.309	8	9	9.000	0.000	9	9	9.000
smf06sp2	0.000	8	4	5.750	1.258	7	8	8.750	0.500	9	7	8.500
smf06sp3	0.000	8	6	7.000	0.816	8	8	8.750	0.500	9	7	8.500
smf07sp1	1.414	8	3	5.750	1.893	7	6	8.000	1.414	9	4	5.750
smf08sp1	0.837	9	6	7.600	1.140	9	6	8.000	1.225	9	4	6.200
smf08sp2	0.816	9	7	7.750	0.500	8	3	6.600	2.302	9	1	4.000
smf08sp3	1.140	9	5	7.200	1.789	9	3	7.200	2.490	9	2	4.400
smf09sp1	0.577	6	6	7.500	1.291	9	6	8.000	1.225	9	3	5.200
smf10sp1	1.304	5	5	6.600	1.517	9	1	6.000	3.162	9	1	4.800
smf10sp2	1.140	7	5	6.600	1.517	9	1	1.800	1.304	4	1	1.000
smf11sp1	0.837	9	8	8.600	0.548	9	8	8.833	0.408	9	7	8.167
smf11sp2	3.215	9	8	8.667	0.577	9	5	7.750	1.893	9	5	6.500

space	E12StdDev	E12Max	E13Min	E13Mean	E13StdDev	E13Max	E14Min	E14Mean	E14StdDev	E14Max	E15Min	E15Mean
nyc01sp1	2.160	9	3	5.667	2.658	9	5	6.833	1.329	9	3	6.500
nyc01sp2	2.639	9	1	4.167	1.941	7	1	4.000	2.449	6	1	3.833
nyc02sp1	1.799	9	4	6.857	1.574	9	1	3.571	1.988	7	2	3.714
nyc02sp2	1.574	9	3	6.286	1.604	8	3	5.857	1.773	8	4	6.000
nyc04sp1	0.787	5	2	3.857	2.116	8	3	5.857	2.193	9	4	5.286
nyc04sp2	0.976	6	2	4.000	1.414	6	2	5.286	2.752	9	2	5.143
nyc05sp1	2.059	9	4	5.857	1.864	8	3	4.429	1.718	8	3	3.714
nyc05sp2	2.059	8	3	5.857	1.864	8	1	3.286	2.059	7	2	4.143
nyc08sp1	1.761	6	1	2.167	0.983	4	2	5.167	2.927	9	2	3.333
nyc08sp2	2.121	4	1	2.000	1.414	3	2	5.500	4.950	9	3	4.000
nyc09sp1	0.577	8	7	7.500	0.577	8	3	5.750	1.893	7	1	3.250
sea01sp1	1.813	8	3	5.714	2.289	8	4	7.000	1.826	9	4	6.167
sea01sp2	2.563	9	3	4.429	1.397	6	2	4.429	2.149	7	1	3.571
sea01sp3	2.628	9	2	6.714	2.289	9	2	5.286	2.812	9	1	4.286
sea02sp1	1.113	9	3	6.857	1.952	9	1	4.833	2.787	9	2	4.571
sea02sp2	0.756	3	1	2.429	0.787	3	3	6.000	2.380	9	3	4.286
sea02sp3	1.291	8	2	5.143	2.035	8	2	4.857	2.795	9	1	3.571
sea03sp1	1.291	9	4	6.286	1.976	9	1	3.286	2.289	7	1	3.429
sea03sp2	1.215	9	6	6.714	0.951	8	2	7.571	2.573	9	3	7.143
sea04sp1	1.033	9	6	6.833	0.983	8	2	5.833	2.483	9	2	5.000
sea04sp2	0.983	9	5	7.333	1.366	9	4	7.167	1.722	9	4	6.333
sea06sp1	1.722	6	2	3.500	1.378	5	3	5.500	2.168	9	1	4.667
sea06sp2	1.949	8	3	5.500	1.517	7	4	6.500	1.871	9	3	5.000
sea06sp3	0.816	9	5	8.167	1.602	9	1	4.167	2.927	8	2	4.833
sea06sp4	1.000	9	1	6.200	3.114	9	1	5.000	3.742	9	1	5.200
sea07sp1	2.137	7	3	4.833	1.169	6	3	6.000	2.191	9	4	5.333
sea07sp2	2.251	8	3	6.500	1.871	8	1	3.500	3.146	8	1	3.000
sea07sp3	1.095	9	5	7.600	1.517	9	3	6.500	2.074	9	3	5.833
sfo01sp1	0.577	4	3	4.333	1.155	5	2	3.667	2.887	7	2	3.667
sfo01sp2	1.155	7	4	5.000	1.000	6	3	4.667	2.082	7	4	5.500
sfo01sp4	0.577	7	6	6.667	0.577	7	7	7.667	0.577	8	6	7.000
sfo02sp1	1.708	7	4	5.500	1.732	7	5	6.750	1.258	8	3	5.500
sfo02sp3	1.000	4	2	2.250	0.500	3	2	5.750	2.500	7	2	3.500
sfo04sp1	2.160	9	4	5.500	1.291	7	2	3.250	1.500	5	1	3.500
sfo04sp2	2.500	8	3	4.250	0.957	5	3	6.000	2.160	8	3	6.250
sfo05sp1	1.140	4	2	3.200	0.837	4	2	6.200	2.490	8	2	5.200
sfo05sp2	0.447	2	1	1.800	0.837	3	5	7.200	1.483	9	4	6.600
sfo05sp3	3.050	8	1	3.200	1.483	5	3	5.400	2.510	9	3	5.400
sfo05sp4	1.949	6	1	2.800	1.095	4	3	4.600	1.817	7	3	4.200
sfo06sp1	1.095	9	6	7.200	0.837	8	4	6.800	1.643	8	4	6.800
sfo06sp2	0.500	8	8	8.250	0.500	9	3	6.750	2.630	9	4	5.750
sfo07sp1	0.894	9	6	6.800	1.095	8	3	5.400	2.191	7	3	4.800
smf02sp1	2.236	6	1	1.200	0.447	2	1	5.800	3.271	9	1	4.600
smf03sp1	0.447	9	7	8.400	0.894	9	3	6.800	2.280	9	4	6.600
smf03sp2	1.789	9	5	6.600	1.140	8	7	8.000	1.000	9	6	7.000
smf04sp1	1.871	8	1	4.000	2.121	6	4	5.800	1.483	8	4	6.000
smf04sp2	2.191	9	2	4.400	2.510	7	8	8.200	0.447	9	7	7.600
smf04sp3	0.548	9	8	8.400	0.548	9	7	7.600	0.548	8	7	7.600
smf05sp1	1.000	9	7	7.250	0.500	8	8	8.500	0.577	9	6	7.250
smf06sp1	0.000	9	8	8.250	0.500	9	3	6.750	2.500	8	3	6.250
smf06sp2	1.000	9	8	8.250	0.500	9	8	8.250	0.500	9	8	8.000
smf06sp3	1.000	9	8	8.000	0.000	8	8	8.250	0.500	9	6	7.250
smf07sp1	2.363	9	4	5.500	1.915	8	4	7.000	2.160	9	4	5.750
smf08sp1	1.643	8	4	5.400	1.517	7	3	6.800	2.490	9	3	5.400
smf08sp2	2.000	6	1	3.800	1.924	6	3	6.000	1.732	7	3	5.600
smf08sp3	2.510	7	2	4.800	2.588	8	4	6.600	1.673	8	4	6.000
smf09sp1	1.789	7	2	3.800	1.483	6	1	3.800	2.775	8	2	4.000
smf10sp1	2.490	7	1	4.500	2.646	7	2	4.800	2.775	9	1	2.000
smf10sp2	0.000	1	1	1.400	0.548	2	4	7.000	2.739	9	1	3.800
smf11sp1	0.983	9	7	7.500	0.548	8	6	7.833	1.169	9	6	7.167
smf11sp2	1.915	9	2	5.250	2.363	7	8	8.750	0.500	9	8	8.750

space	E15StdDev	E15Max	E18Min	E18Mean	E18StdDev	E18Max	E19Min	E19Mean	E19StdDev	E19Max	E20Min	E20Mean
nyc01sp1	1.975	9	3	6.333	2.066	8	3	6.333	2.160	9	4	6.833
nyc01sp2	1.941	6	4	5.833	1.329	8	4	5.667	1.506	8	2	4.667
nyc02sp1	1.380	5	5	6.714	0.951	8	6	7.143	0.690	8	6	7.429
nyc02sp2	1.155	8	5	7.000	1.291	8	3	5.857	1.676	7	3	6.286
nyc04sp1	2.215	9	3	5.000	2.160	9	3	5.000	2.082	9	5	6.714
nyc04sp2	2.795	9	4	6.000	1.528	9	4	6.000	1.528	9	5	7.000
nyc05sp1	1.496	7	4	6.000	2.000	8	4	6.000	1.915	8	4	6.143
nyc05sp2	2.193	8	3	5.286	1.254	7	3	5.857	1.345	7	4	6.000
nyc08sp1	1.211	5	2	2.833	0.753	4	2	2.667	0.816	4	3	4.167
nyc08sp2	1.414	5	3	3.000	0.000	3	2	2.500	0.707	3	3	3.000
nyc09sp1	2.062	6	6	7.500	1.000	8	7	7.500	0.577	8	7	8.000
sea01sp1	2.137	9	4	6.000	1.414	8	4	6.429	1.397	8	3	5.833
sea01sp2	1.902	7	2	4.571	1.618	7	4	5.714	1.113	7	6	7.429
sea01sp3	2.690	8	5	7.000	1.000	8	6	7.000	0.816	8	7	7.857
sea02sp1	1.397	6	7	7.714	0.756	9	4	6.857	1.345	8	6	7.429
sea02sp2	0.951	6	2	3.000	0.816	4	3	4.000	1.000	5	3	4.429
sea02sp3	1.397	5	5	6.714	1.113	8	4	6.571	1.272	8	5	6.714
sea03sp1	2.225	7	4	6.000	1.732	8	3	6.571	1.988	9	5	6.857
sea03sp2	2.268	9	3	6.857	2.193	9	3	6.143	2.035	9	3	6.429
sea04sp1	1.673	6	6	7.333	1.033	9	3	5.667	2.422	9	5	6.500
sea04sp2	1.366	8	7	8.167	0.753	9	7	7.667	0.516	8	6	7.333
sea06sp1	1.966	6	3	4.833	1.472	6	3	6.000	2.191	9	7	7.833
sea06sp2	1.549	7	4	6.000	1.265	7	6	7.167	0.753	8	7	8.000
sea06sp3	1.722	7	7	8.000	0.894	9	7	8.000	0.632	9	9	9.000
sea06sp4	3.347	9	2	5.600	3.362	9	2	7.000	2.915	9	1	3.000
sea07sp1	1.211	7	3	4.667	1.211	6	4	5.333	0.816	6	5	6.667
sea07sp2	2.530	7	3	6.167	2.137	8	4	6.167	1.472	8	6	6.667
sea07sp3	2.229	8	6	8.333	1.211	9	6	7.833	1.169	9	6	8.167
sfo01sp1	2.082	6	4	5.667	1.528	7	5	7.000	1.732	8	4	5.000
sfo01sp2	2.121	7	4	5.000	1.000	6	4	4.333	0.577	5	4	5.000
sfo01sp4	1.000	8	7	7.000	0.000	7	6	6.667	0.577	7	6	6.667
sfo02sp1	2.082	8	3	5.500	1.915	7	4	6.000	1.414	7	3	3.750
sfo02sp3	1.291	5	3	4.500	1.732	7	2	2.750	0.500	3	2	2.750
sfo04sp1	2.380	6	4	6.000	1.414	7	4	5.500	1.732	8	6	6.750
sfo04sp2	2.217	8	3	4.250	0.957	5	3	4.750	1.258	6	5	6.250
sfo05sp1	2.168	8	2	2.600	0.894	4	2	2.750	0.957	4	2	3.800
sfo05sp2	2.074	9	1	2.000	1.000	3	1	2.000	1.000	3	1	3.000
sfo05sp3	1.817	8	3	5.400	1.517	7	3	4.800	1.304	6	3	5.400
sfo05sp4	1.304	6	3	3.400	0.548	4	3	4.000	1.000	5	3	4.000
sfo06sp1	1.643	8	8	8.000	0.000	8	7	7.800	0.447	8	6	7.400
sfo06sp2	1.258	7	7	8.000	0.816	9	8	8.500	0.577	9	7	8.000
sfo07sp1	2.049	7	7	7.800	0.447	8	7	7.800	0.837	9	5	7.200
smf02sp1	2.881	8	1	1.600	0.894	3	1	2.200	0.837	3	3	3.600
smf03sp1	1.817	9	9	9.000	0.000	9	8	8.800	0.447	9	7	7.800
smf03sp2	1.000	8	7	7.600	0.548	8	6	7.200	0.837	8	7	7.800
smf04sp1	1.581	8	3	6.000	1.871	8	5	5.600	0.894	7	4	5.600
smf04sp2	0.548	8	4	5.200	1.789	8	3	5.200	1.483	7	4	5.600
smf04sp3	0.894	9	8	8.400	0.548	9	6	7.600	1.342	9	5	7.400
smf05sp1	0.957	8	8	8.000	0.000	8	6	7.000	1.414	9	2	4.750
smf06sp1	2.217	8	7	8.250	0.957	9	6	7.500	1.000	8	4	7.000
smf06sp2	0.000	8	8	8.750	0.500	9	8	8.750	0.500	9	8	8.000
smf06sp3	0.957	8	8	8.500	0.577	9	7	7.750	0.957	9	7	8.000
smf07sp1	2.062	8	5	6.250	1.258	8	3	6.000	2.160	8	6	6.750
smf08sp1	1.949	8	5	6.600	1.140	8	5	6.600	1.140	8	6	7.400
smf08sp2	1.517	7	2	4.800	1.643	6	2	5.400	2.074	7	4	6.800
smf08sp3	1.581	8	2	5.600	2.510	8	3	5.600	1.949	8	3	5.800
smf09sp1	1.581	6	3	4.800	1.643	7	4	4.800	0.837	6	3	5.400
smf10sp1	0.707	3	3	4.000	0.816	5	3	4.400	1.140	6	1	1.800
smf10sp2	3.114	9	1	1.250	0.500	2	1	1.800	1.304	4	1	1.600
smf11sp1	0.983	9	6	7.600	1.140	9	6	7.333	1.211	9	7	7.833
smf11sp2	0.500	9	7	8.000	0.816	9	6	7.250	1.258	9	6	7.000

space	E20StdDev	E20Max	E21Min	E21Mean	E21StdDev	E21Max	E22Min	E22Mean	E22StdDev	E22Max	E23Min	E23Mean
nyc01sp1	1.722	9	6	7.833	1.169	9	5	7.000	2.000	9	3	6.000
nyc01sp2	1.966	7	2	3.000	1.000	4	4	5.333	1.033	7	4	5.167
nyc02sp1	1.134	9	6	7.000	1.155	9	4	5.429	1.512	8	4	6.286
nyc02sp2	1.704	8	2	4.857	1.773	7	5	6.429	0.787	7	4	6.429
nyc04sp1	1.380	9	4	7.286	1.799	9	6	6.714	0.756	8	4	6.000
nyc04sp2	1.528	9	5	7.429	1.512	9	4	6.143	1.676	8	4	6.000
nyc05sp1	1.773	8	4	5.857	1.464	8	3	4.429	1.272	7	3	3.857
nyc05sp2	1.414	8	3	5.429	1.813	8	4	4.714	0.756	6	4	6.000
nyc08sp1	0.983	5	4	4.833	0.753	6	3	4.250	1.893	7	3	3.667
nyc08sp2	0.000	3	4	4.000	0.000	4	5	6.000	1.414	7	3	3.500
nyc09sp1	0.816	9	8	8.750	0.500	9	5	6.000	1.155	7	7	7.250
sea01sp1	1.722	8	3	6.714	1.976	8	5	7.000	1.528	9	6	7.167
sea01sp2	0.787	8	6	8.143	1.215	9	4	6.286	1.254	7	5	6.833
sea01sp3	0.690	9	4	7.714	1.799	9	5	6.714	1.380	9	6	7.333
sea02sp1	1.134	9	5	7.143	1.345	9	4	6.571	1.618	9	4	6.429
sea02sp2	0.976	6	2	4.857	1.773	7	3	5.143	1.345	7	2	4.286
sea02sp3	1.113	8	3	5.857	1.574	8	4	5.857	1.952	9	3	5.143
sea03sp1	1.069	8	3	6.571	1.813	8	3	4.571	1.618	7	3	6.000
sea03sp2	1.813	9	2	3.200	1.304	5	6	7.571	1.397	9	4	6.714
sea04sp1	1.049	8	3	4.833	2.041	7	5	6.500	1.517	9	4	6.333
sea04sp2	0.816	8	6	7.667	1.211	9	7	7.000	0.000	7	6	7.400
sea06sp1	0.753	9	9	9.000	0.000	9	5	6.800	1.304	8	5	7.000
sea06sp2	0.894	9	5	8.333	1.633	9	5	6.833	0.983	8	5	7.000
sea06sp3	0.000	9	9	9.000	0.000	9	4	6.000	1.789	9	5	6.667
sea06sp4	2.345	7	1	1.000	0.000	1	1	5.250	3.862	9	5	7.000
sea07sp1	1.633	9	5	7.667	1.751	9	4	6.500	1.378	8	4	6.600
sea07sp2	0.816	8	6	6.833	1.169	9	3	5.667	2.160	8	6	7.000
sea07sp3	1.169	9	6	8.000	1.095	9	6	7.000	0.632	8	6	7.600
sfo01sp1	1.732	7	2	2.000	0.000	2	4	5.000	1.732	7	5	6.333
sfo01sp2	1.000	6	3	4.333	1.528	6	3	3.667	0.577	4	5	6.333
sfo01sp4	0.577	7	4	5.667	1.528	7	5	6.000	1.000	7	6	6.667
sfo02sp1	1.500	6	2	3.250	1.258	5	3	4.500	1.291	6	4	6.000
sfo02sp3	0.500	3	2	2.000	0.000	2	3	4.000	1.155	5	3	5.000
sfo04sp1	0.500	7	7	7.750	0.957	9	4	6.000	1.633	8	5	6.000
sfo04sp2	1.258	8	5	6.500	1.291	8	5	6.500	1.000	7	5	6.333
sfo05sp1	1.789	6	2	3.400	1.140	5	3	5.600	1.673	7	2	5.000
sfo05sp2	1.581	5	1	1.800	0.837	3	3	6.000	2.582	9	2	2.333
sfo05sp3	1.517	7	2	3.600	1.140	5	4	5.750	1.500	7	4	6.000
sfo05sp4	1.414	6	2	3.200	0.837	4	4	6.200	1.304	7	3	4.000
sfo06sp1	1.342	9	1	3.500	2.646	7	4	5.600	1.342	7	7	7.200
sfo06sp2	0.816	9	1	1.500	0.707	2	3	5.000	1.414	6	7	7.750
sfo07sp1	1.483	9	5	5.500	1.000	7	4	5.800	1.643	7	7	7.200
smf02sp1	1.342	6	4	6.000	1.871	8	4	5.400	1.673	8	2	4.800
smf03sp1	0.837	9	7	7.800	0.837	9	6	6.800	1.095	8	6	8.000
smf03sp2	0.837	9	8	8.400	0.548	9	6	7.200	0.837	8	7	7.800
smf04sp1	1.517	7	2	5.600	2.702	9	7	7.800	0.837	9	6	7.500
smf04sp2	1.817	8	3	5.400	2.074	8	7	7.800	0.447	8	5	6.600
smf04sp3	1.673	9	5	6.400	1.342	8	5	7.000	1.225	8	6	7.250
smf05sp1	2.500	8	1	1.333	0.577	2	7	7.750	0.500	8	6	7.000
smf06sp1	2.000	8	7	7.750	0.500	8	3	3.250	0.500	4	4	6.500
smf06sp2	0.000	8	7	7.250	0.500	8	6	7.000	0.816	8	7	8.000
smf06sp3	0.816	9	6	6.750	0.500	7	6	6.750	0.500	7	7	7.250
smf07sp1	0.957	8	6	6.000	0.000	6	5	6.000	1.414	7	5	6.500
smf08sp1	0.894	8	6	7.600	1.140	9	5	6.800	1.304	8	6	7.000
smf08sp2	1.643	8	4	6.600	2.074	9	3	5.200	1.924	8	5	5.600
smf08sp3	1.643	7	6	7.200	0.837	8	4	6.000	1.871	8	5	6.400
smf09sp1	1.517	7	5	6.600	1.140	8	4	5.000	1.000	6	3	4.000
smf10sp1	0.837	3	2	4.200	2.387	8	3	4.200	1.643	7	2	4.200
smf10sp2	0.894	3	3	5.000	1.871	8	2	4.200	2.168	7	1	1.800
smf11sp1	0.753	9	6	6.833	0.753	8	7	7.667	0.816	9	7	7.500
smf11sp2	0.816	8	2	4.000	2.449	7	8	8.500	0.577	9	7	8.000

space	E23StdDev	E23Max	E24Min	E24Mean	E24StdDev	E24Max	E25Min	E25Mean	E25StdDev	E25Max	E26Min	E26Mean
nyc01sp1	2.000	8	3	5.833	2.041	8	4	6.833	1.472	8	4	6.500
nyc01sp2	0.983	6	4	5.500	1.049	7	4	6.333	1.366	8	3	6.000
nyc02sp1	1.496	9	4	6.429	1.512	9	7	7.571	0.787	9	4	6.286
nyc02sp2	1.272	8	4	6.857	1.464	8	4	6.714	1.380	8	4	6.143
nyc04sp1	1.414	8	4	6.571	1.902	9	4	6.286	2.059	9	4	5.857
nyc04sp2	1.673	8	4	6.000	1.826	9	4	5.714	1.799	8	2	5.429
nyc05sp1	0.690	5	4	5.571	1.988	8	5	6.714	1.496	9	4	4.857
nyc05sp2	1.414	8	2	5.429	2.299	8	4	6.000	1.414	7	4	5.143
nyc08sp1	0.816	5	3	3.333	0.816	5	3	4.500	1.643	7	3	4.000
nyc08sp2	0.707	4	3	3.500	0.707	4	3	4.000	1.414	5	3	3.500
nyc09sp1	0.500	8	4	6.500	1.732	8	8	8.250	0.500	9	4	6.750
sea01sp1	1.169	9	4	6.286	1.496	8	6	7.286	1.113	9	4	6.429
sea01sp2	1.169	8	5	6.571	0.787	7	3	6.571	2.070	9	3	5.571
sea01sp3	1.033	9	6	7.286	1.113	9	4	7.286	1.799	9	3	6.333
sea02sp1	1.813	9	6	6.571	0.787	8	7	8.000	0.577	9	4	6.286
sea02sp2	1.799	7	2	4.000	1.732	7	2	3.857	1.574	6	3	3.857
sea02sp3	1.574	8	3	4.857	1.574	8	5	6.714	1.496	9	3	5.571
sea03sp1	2.236	9	3	6.286	1.976	9	6	7.571	0.976	9	4	4.857
sea03sp2	1.799	9	6	7.429	0.976	9	6	7.429	1.272	9	3	6.571
sea04sp1	1.366	8	4	6.833	1.835	9	6	7.333	1.033	9	5	6.667
sea04sp2	0.894	8	4	6.333	1.862	8	7	8.000	0.707	9	5	6.800
sea06sp1	1.225	8	1	5.167	2.229	7	3	5.500	1.643	7	4	6.167
sea06sp2	1.225	8	2	5.500	2.510	8	5	6.833	0.983	8	4	6.833
sea06sp3	1.366	9	3	5.833	2.137	8	7	8.333	1.033	9	4	6.333
sea06sp4	2.000	9	7	7.800	1.095	9	7	8.400	0.894	9	6	7.000
sea07sp1	1.673	8	4	6.500	1.517	8	4	6.000	1.414	8	3	6.000
sea07sp2	0.894	8	2	4.833	2.229	8	7	7.333	0.516	8	3	6.000
sea07sp3	1.140	9	5	7.167	1.472	9	6	8.000	1.095	9	6	7.167
sfo01sp1	1.528	8	5	6.333	1.528	8	6	6.667	1.155	8	6	6.667
sfo01sp2	1.528	8	5	6.333	1.528	8	5	6.667	1.528	8	5	6.333
sfo01sp4	0.577	7	7	7.333	0.577	8	7	7.667	0.577	8	6	7.333
sfo02sp1	1.633	8	5	6.250	0.957	7	4	6.500	1.732	8	4	5.750
sfo02sp3	2.160	8	2	3.000	0.816	4	3	4.250	1.258	6	3	3.250
sfo04sp1	1.155	7	4	4.500	0.577	5	5	6.500	1.000	7	5	6.000
sfo04sp2	1.155	7	5	5.750	0.957	7	5	6.250	1.258	8	5	6.500
sfo05sp1	2.236	8	2	3.800	1.643	6	2	4.600	2.191	8	2	4.600
sfo05sp2	0.577	3	2	2.750	0.500	3	2	2.750	0.957	4	2	3.500
sfo05sp3	1.414	7	2	3.400	1.673	6	3	5.200	1.924	8	3	5.000
sfo05sp4	0.816	5	3	4.800	1.304	6	3	4.400	1.342	6	3	4.200
sfo06sp1	0.447	8	8	8.200	0.447	9	8	8.000	0.000	8	3	6.800
sfo06sp2	0.500	8	8	8.250	0.500	9	8	8.500	0.577	9	6	7.500
sfo07sp1	0.447	8	7	7.600	0.548	8	7	7.600	0.894	9	2	6.000
smf02sp1	1.789	6	3	4.800	1.643	7	3	5.600	1.817	8	4	5.400
smf03sp1	1.414	9	7	8.400	0.894	9	8	8.600	0.548	9	4	7.600
smf03sp2	1.095	9	6	8.000	1.414	9	8	8.600	0.548	9	3	7.200
smf04sp1	1.000	8	5	6.400	1.140	8	4	6.200	2.049	8	4	6.400
smf04sp2	1.517	8	5	6.600	1.517	8	2	6.000	2.828	8	3	6.200
smf04sp3	0.957	8	7	8.200	0.837	9	6	8.200	1.304	9	4	6.800
smf05sp1	1.000	8	8	8.250	0.500	9	8	8.500	0.577	9	4	6.500
smf06sp1	1.732	8	7	7.750	0.500	8	8	8.500	0.577	9	4	6.000
smf06sp2	0.816	9	8	8.500	0.577	9	8	8.500	0.577	9	8	8.000
smf06sp3	0.500	8	6	7.500	1.291	9	8	8.250	0.500	9	7	7.250
smf07sp1	1.000	7	5	6.750	1.708	9	4	6.500	1.915	8	5	6.750
smf08sp1	1.000	8	5	7.000	1.414	8	6	7.000	1.000	8	6	6.800
smf08sp2	0.894	7	4	5.400	0.894	6	2	5.600	2.191	8	2	5.400
smf08sp3	1.517	8	5	6.400	1.517	8	3	6.200	2.049	8	3	6.000
smf09sp1	1.000	5	4	5.600	1.140	7	4	5.000	1.000	6	4	4.750
smf10sp1	1.789	6	3	5.600	2.408	9	6	7.400	1.140	9	2	3.400
smf10sp2	1.304	4	1	2.200	0.837	3	1	2.400	0.894	3	1	2.400
smf11sp1	0.577	8	6	7.667	1.033	9	7	8.000	0.632	9	6	7.500
smf11sp2	1.000	9	7	8.000	0.816	9	2	6.500	3.109	9	8	8.250

space	E26StdDev	E26Max	E27Min	E27Mean	E27StdDev	E27Max	E28Min	E28Mean	E28StdDev	E28Max	E29Min	E29Mean
nyc01sp1	1.643	8	1	3.667	2.944	7	5	6.833	1.472	9	6	8.000
nyc01sp2	1.549	7	4	5.833	1.472	7	2	3.667	1.506	6	2	3.833
nyc02sp1	1.380	8	6	6.857	1.069	9	2	3.714	1.380	5	2	3.714
nyc02sp2	1.345	8	4	6.857	1.676	9	4	6.286	1.380	8	6	6.571
nyc04sp1	1.773	9	2	5.429	1.813	7	3	5.143	2.340	9	3	5.714
nyc04sp2	2.299	9	2	5.429	1.813	7	2	4.714	2.430	9	2	5.429
nyc05sp1	1.215	7	4	5.714	1.496	8	3	5.000	1.633	7	3	4.714
nyc05sp2	1.345	7	2	4.143	1.574	7	1	4.000	2.160	7	1	3.286
nyc08sp1	1.673	7	4	5.000	0.894	6	3	4.000	0.894	5	3	4.167
nyc08sp2	0.707	4	4	5.000	1.414	6	2	3.500	2.121	5	1	2.500
nyc09sp1	1.893	8	1	2.500	1.291	4	2	4.250	2.062	6	1	3.000
sea01sp1	1.618	9	4	6.143	1.773	9	5	6.857	1.069	8	5	7.571
sea01sp2	1.397	7	2	4.714	1.799	7	1	3.857	2.410	6	1	3.000
sea01sp3	1.751	8	4	6.000	1.528	8	2	4.000	2.517	8	2	2.833
sea02sp1	1.254	7	4	5.714	1.113	7	1	3.286	1.799	6	1	2.857
sea02sp2	0.900	5	3	5.429	1.813	7	3	3.571	0.787	5	3	4.143
sea02sp3	1.397	7	4	6.000	1.155	7	2	3.143	0.690	4	3	4.000
sea03sp1	0.900	6	2	3.857	1.345	6	1	2.429	1.272	5	1	2.286
sea03sp2	1.988	9	1	2.600	3.050	8	2	6.667	2.658	9	2	6.167
sea04sp1	1.366	9	1	2.500	2.258	7	2	4.167	1.835	6	2	4.167
sea04sp2	1.095	8	6	7.000	0.632	8	3	4.500	1.761	7	2	4.333
sea06sp1	1.472	8	3	5.333	1.506	7	1	3.833	1.722	6	2	4.667
sea06sp2	1.472	8	3	5.667	1.751	7	2	5.167	2.041	8	2	4.833
sea06sp3	1.506	8	7	8.167	0.983	9	1	4.167	2.927	9	1	3.833
sea06sp4	1.225	9	1	1.200	0.447	2	1	3.600	3.209	9	1	7.000
sea07sp1	1.549	7	5	6.500	1.225	8	3	5.333	1.862	7	7	8.000
sea07sp2	1.673	7	2	3.667	1.966	6	1	2.667	1.506	5	1	2.000
sea07sp3	1.329	9	2	3.600	2.191	6	2	6.000	2.098	8	6	7.667
sfo01sp1	1.155	8	2	3.333	1.528	5	2	3.333	1.528	5	6	7.333
sfo01sp2	1.155	7	6	7.000	1.000	8	4	5.000	1.000	6	4	5.667
sfo01sp4	1.155	8	7	7.333	0.577	8	6	6.667	0.577	7	6	6.667
sfo02sp1	1.258	7	4	5.500	1.732	7	4	5.250	1.500	7	4	4.500
sfo02sp3	0.500	4	2	2.750	0.957	4	2	2.750	0.957	4	3	3.500
sfo04sp1	1.155	7	3	5.000	1.414	6	2	3.250	0.957	4	2	2.500
sfo04sp2	1.291	8	3	4.000	0.816	5	3	5.000	1.826	7	3	5.250
sfo05sp1	2.191	8	2	4.000	1.871	7	3	4.800	1.483	7	3	6.800
sfo05sp2	1.291	5	1	3.500	3.109	8	4	5.800	1.789	8	5	7.200
sfo05sp3	2.121	8	1	3.000	2.000	6	3	4.400	1.949	7	4	7.200
sfo05sp4	1.095	5	3	3.600	0.894	5	3	4.800	1.095	6	3	5.600
sfo06sp1	2.168	8	1	3.750	2.500	7	5	6.000	1.414	8	4	6.600
sfo06sp2	1.291	9	1	3.333	3.215	7	3	6.000	2.449	8	2	5.250
sfo07sp1	2.345	8	2	5.200	2.387	8	2	5.000	2.345	7	3	4.600
smf02sp1	1.949	8	1	2.250	2.500	6	2	5.250	2.754	8	4	6.000
smf03sp1	2.074	9	5	6.800	1.789	9	3	6.800	2.280	9	2	6.200
smf03sp2	2.387	9	3	5.400	1.817	7	4	7.000	2.345	9	4	6.800
smf04sp1	1.817	8	3	5.600	1.817	8	4	6.600	1.517	8	4	6.200
smf04sp2	2.490	8	4	6.200	1.924	9	4	7.200	1.789	8	7	7.800
smf04sp3	1.924	9	7	7.600	0.894	9	4	6.800	1.643	8	8	8.200
smf05sp1	1.915	8	1	1.250	0.500	2	7	8.000	0.816	9	8	8.500
smf06sp1	1.414	7	3	5.750	2.217	8	2	6.000	2.708	8	6	7.250
smf06sp2	0.000	8	7	8.000	0.816	9	7	7.500	0.577	8	8	8.500
smf06sp3	0.500	8	7	7.250	0.500	8	5	6.500	1.291	8	8	8.500
smf07sp1	1.258	8	3	4.500	1.732	6	3	6.000	2.160	8	3	5.750
smf08sp1	0.837	8	6	7.000	1.000	8	3	5.200	2.280	8	3	5.400
smf08sp2	1.949	7	4	6.000	1.225	7	3	5.400	1.817	8	3	5.600
smf08sp3	1.871	8	5	6.600	1.517	8	5	6.200	0.837	7	5	6.800
smf09sp1	1.500	7	1	3.200	2.387	7	1	3.200	2.280	7	1	2.000
smf10sp1	1.140	5	4	5.600	0.894	6	1	2.000	0.707	3	2	3.800
smf10sp2	0.894	3	1	1.400	0.548	2	1	3.400	3.286	9	2	4.000
smf11sp1	1.049	9	2	5.667	2.338	8	6	7.000	0.894	8	2	6.000
smf11sp2	0.500	9	2	4.000	3.367	9	8	8.750	0.500	9	9	9.000

space	E29StdDev	E29Max	E30Min	E30Mean	E30StdDev	E30Max	E31Min	E31Mean	E31StdDev	E31Max	E32Min	E32Mean
nyc01sp1	1.095	9	4	6.000	2.449	9	4	6.600	1.817	9	6	7.667
nyc01sp2	1.602	6	2	4.167	1.835	6	2	4.600	2.408	7	2	5.167
nyc02sp1	1.704	6	2	3.429	0.787	4	2	4.857	1.676	7	2	3.714
nyc02sp2	0.787	8	4	6.143	1.676	9	4	6.429	1.512	8	4	6.000
nyc04sp1	2.289	9	4	5.857	1.773	8	4	6.000	1.528	8	4	5.857
nyc04sp2	2.573	9	2	5.429	2.299	8	2	5.500	2.510	8	3	5.143
nyc05sp1	1.890	7	3	4.714	1.704	7	2	3.857	1.773	7	4	4.286
nyc05sp2	2.215	7	3	4.429	1.618	7	1	4.143	2.035	7	2	4.000
nyc08sp1	0.983	5	3	4.500	1.915	7	3	4.500	1.225	6	5	5.833
nyc08sp2	2.121	4	4	5.500	2.121	7	4	5.500	2.121	7	6	7.500
nyc09sp1	1.633	5	3	4.250	1.500	6	3	5.250	2.062	7	3	3.750
sea01sp1	1.397	9	4	6.286	1.254	7	3	5.429	2.070	8	5	7.571
sea01sp2	2.082	6	1	4.571	2.225	7	1	5.286	2.215	8	2	5.000
sea01sp3	1.169	5	2	4.286	2.059	7	2	4.857	2.340	8	3	5.571
sea02sp1	1.773	6	3	4.429	1.134	6	2	4.714	1.890	7	3	4.714
sea02sp2	1.574	7	3	3.857	1.215	6	2	3.429	0.976	5	4	6.143
sea02sp3	1.155	6	4	4.571	0.787	6	2	4.143	1.773	7	4	5.167
sea03sp1	1.380	5	2	3.429	1.272	6	2	4.143	1.464	6	1	3.286
sea03sp2	2.317	8	3	7.000	2.236	8	7	8.000	1.000	9	3	7.167
sea04sp1	2.041	6	4	6.500	1.643	9	2	4.000	1.897	7	3	5.833
sea04sp2	2.160	7	4	5.500	2.121	7	4	5.500	1.732	7	4	5.167
sea06sp1	2.251	7	4	6.667	1.633	8	3	4.500	1.291	6	4	6.667
sea06sp2	2.714	8	4	6.000	1.265	7	4	5.250	0.957	6	4	6.833
sea06sp3	3.061	9	2	5.000	3.033	9	2	5.500	2.429	8	1	2.167
sea06sp4	4.000	9	1	4.000	3.559	8	2	6.750	3.304	9	2	6.200
sea07sp1	0.632	9	3	5.500	2.258	8	4	6.500	1.915	8	6	8.167
sea07sp2	1.265	4	1	4.500	2.429	7	1	3.333	3.215	7	1	3.000
sea07sp3	1.366	9	4	6.000	1.581	8	5	6.500	1.225	8	6	8.000
sfo01sp1	1.155	8	3	4.667	2.082	7	5	6.667	1.528	8	4	4.667
sfo01sp2	1.528	7	2	3.333	2.309	6	4	5.333	1.528	7	4	5.000
sfo01sp4	0.577	7	6	6.667	1.155	8	7	7.000	0.000	7	7	7.667
sfo02sp1	0.577	5	4	5.750	1.258	7	5	6.500	1.000	7	4	5.000
sfo02sp3	0.577	4	2	3.250	0.957	4	3	4.500	1.732	7	4	5.000
sfo04sp1	0.577	3	2	3.750	1.258	5	2	4.333	2.517	7	3	3.250
sfo04sp2	2.217	8	4	5.250	1.500	7	4	6.000	2.828	8	5	6.500
sfo05sp1	2.490	9	3	5.000	1.581	7	3	6.500	2.380	8	4	6.800
sfo05sp2	1.643	9	6	7.800	1.304	9	6	7.750	1.258	9	8	8.400
sfo05sp3	2.168	9	3	4.500	1.915	7	4	6.400	1.517	8	7	8.000
sfo05sp4	1.949	8	4	5.400	1.140	7	4	5.250	1.258	7	3	5.000
sfo06sp1	1.673	8	5	6.400	0.894	7	7	7.500	0.577	8	4	6.600
sfo06sp2	2.363	7	4	5.250	0.957	6	4	6.250	1.708	8	5	6.750
sfo07sp1	1.517	6	4	4.800	1.095	6	4	5.500	1.291	7	3	5.200
smf02sp1	1.826	8	3	4.750	2.363	8	4	5.500	2.121	7	4	5.750
smf03sp1	2.775	9	3	6.200	1.924	8	3	6.200	2.588	9	4	5.400
smf03sp2	2.168	9	2	5.400	2.302	7	3	5.800	2.168	8	2	4.800
smf04sp1	1.643	8	5	6.800	1.304	8	6	6.667	0.577	7	4	6.200
smf04sp2	0.837	9	7	7.400	0.548	8	7	7.333	0.577	8	5	7.400
smf04sp3	0.447	9	4	6.800	1.643	8	7	7.667	0.577	8	5	6.200
smf05sp1	0.577	9	8	8.000	0.000	8	5	7.000	1.414	8	4	7.000
smf06sp1	0.957	8	2	2.750	1.500	5	6	7.250	0.957	8	1	5.000
smf06sp2	0.577	9	6	7.000	1.155	8	7	7.500	0.577	8	6	7.250
smf06sp3	0.577	9	6	6.500	0.577	7	4	6.500	1.915	8	7	7.500
smf07sp1	2.217	8	5	6.000	1.000	7	4	6.500	1.732	8	5	7.000
smf08sp1	2.408	8	4	6.000	1.633	8	4	6.200	1.483	8	4	5.200
smf08sp2	1.949	8	3	3.600	0.548	4	3	6.000	1.732	7	4	5.600
smf08sp3	1.095	8	4	5.250	1.258	7	5	5.250	0.500	6	5	7.500
smf09sp1	1.000	3	2	3.333	1.528	5	2	3.750	1.258	5	2	3.600
smf10sp1	2.168	7	2	2.600	0.894	4	1	3.200	1.483	5	5	5.800
smf10sp2	2.345	8	2	4.000	2.345	8	2	3.800	2.490	8	5	6.500
smf11sp1	3.098	8	4	6.333	1.211	7	5	6.750	1.258	8	4	6.667
smf11sp2	0.000	9	8	8.750	0.500	9	6	7.500	2.121	9	9	9.000

space	E32StdDev	E32Max	E33Min	E33Mean	E33StdDev	E33Max	E34Min	E34Mean	E34StdDev	E34Max	E35Min	E35Mean
nyc01sp1	1.211	9	3	4.667	1.033	6	2	3.667	1.506	5	3	6.000
nyc01sp2	2.229	8	6	6.667	0.816	8	2	3.500	1.517	6	5	6.667
nyc02sp1	1.704	7	2	4.143	1.574	7	3	3.714	0.488	4	2	4.143
nyc02sp2	1.732	8	3	4.286	0.951	5	2	3.667	1.506	6	4	5.857
nyc04sp1	1.773	8	4	6.000	1.414	8	3	4.714	1.496	7	2	5.714
nyc04sp2	1.952	8	3	5.000	1.633	8	2	4.857	1.574	7	2	5.857
nyc05sp1	0.756	6	3	5.286	1.380	7	1	4.714	1.799	6	5	5.857
nyc05sp2	1.414	6	4	5.143	1.215	7	1	4.286	1.799	6	3	5.714
nyc08sp1	1.602	9	4	5.000	0.632	6	3	4.000	0.632	5	4	4.667
nyc08sp2	2.121	9	4	5.000	1.414	6	4	4.500	0.707	5	4	4.500
nyc09sp1	1.500	6	3	4.750	1.708	7	4	4.250	0.500	5	4	6.000
sea01sp1	1.813	9	2	5.571	2.637	8	2	4.000	2.236	8	4	6.000
sea01sp2	1.732	7	1	5.143	3.078	8	2	3.857	2.340	8	4	6.429
sea01sp3	1.813	8	2	5.143	2.268	8	2	3.286	2.138	8	3	6.143
sea02sp1	1.496	7	3	5.571	1.512	7	3	4.857	1.345	7	4	6.143
sea02sp2	1.215	7	5	6.429	1.134	8	3	5.286	1.254	7	6	6.857
sea02sp3	1.472	7	3	5.857	1.676	8	2	5.143	1.574	7	4	6.571
sea03sp1	1.704	6	1	2.857	1.069	4	1	3.286	1.704	5	2	3.714
sea03sp2	2.401	9	3	6.500	2.345	9	2	3.000	1.265	5	3	5.500
sea04sp1	1.472	7	2	6.333	2.422	8	2	2.833	0.753	4	2	4.333
sea04sp2	1.835	8	5	6.833	1.169	8	2	3.833	1.169	5	3	5.167
sea06sp1	1.506	8	7	8.000	0.632	9	4	5.833	1.722	8	5	7.167
sea06sp2	1.941	9	7	7.667	0.516	8	2	4.833	2.137	8	5	7.667
sea06sp3	1.472	5	2	4.167	2.483	7	1	4.800	2.775	8	5	7.500
sea06sp4	2.588	9	6	7.200	1.304	9	1	3.400	3.050	8	2	6.000
sea07sp1	1.169	9	4	6.167	1.169	7	4	5.167	1.602	8	3	6.167
sea07sp2	1.549	5	1	3.833	2.714	8	1	3.167	2.137	7	5	6.167
sea07sp3	1.095	9	4	6.333	1.506	8	2	4.667	2.066	8	5	7.000
sfo01sp1	1.155	6	6	6.333	0.577	7	2	3.000	1.000	4	2	2.000
sfo01sp2	1.732	7	5	5.667	0.577	6	4	4.000	0.000	4	2	3.000
sfo01sp4	1.155	9	7	7.333	0.577	8	2	3.000	1.414	4	3	3.333
sfo02sp1	1.155	6	4	6.000	1.826	8	4	4.667	0.577	5	2	4.500
sfo02sp3	1.155	6	4	6.000	1.826	8	3	3.333	0.577	4	3	3.500
sfo04sp1	0.500	4	2	4.250	2.217	7	2	2.500	0.577	3	3	4.500
sfo04sp2	1.915	9	4	6.000	1.414	7	2	3.250	1.258	5	5	6.000
sfo05sp1	2.280	9	2	5.800	2.387	8	3	4.600	1.342	6	6	7.000
sfo05sp2	0.548	9	4	7.400	1.949	9	2	3.200	0.837	4	5	7.400
sfo05sp3	1.000	9	8	8.750	0.500	9	5	6.200	1.304	8	7	8.400
sfo05sp4	1.225	6	4	5.800	1.304	7	4	5.000	1.000	6	6	7.000
sfo06sp1	1.673	8	4	6.000	1.871	8	1	3.800	2.588	7	3	6.400
sfo06sp2	1.258	8	6	7.500	1.291	9	2	3.750	1.258	5	5	7.000
sfo07sp1	1.924	8	3	5.200	1.643	7	3	4.000	1.414	6	3	4.400
smf02sp1	1.258	7	6	7.500	1.291	9	Inf	NA	NA	#NAME?	Inf	NA
smf03sp1	1.949	8	2	4.400	1.949	7	Inf	NA	NA	#NAME?	Inf	NA
smf03sp2	2.280	8	2	3.600	1.140	5	Inf	NA	NA	#NAME?	Inf	NA
smf04sp1	1.643	8	5	7.000	1.414	8	1	2.400	1.673	5	5	7.000
smf04sp2	1.517	9	5	7.000	1.414	8	1	2.800	2.049	6	5	7.000
smf04sp3	1.304	8	5	6.800	1.304	8	4	4.800	0.447	5	5	7.000
smf05sp1	2.646	9	7	8.000	0.816	9	1	2.500	1.732	5	1	4.500
smf06sp1	2.944	8	2	5.000	2.160	7	2	4.250	1.708	6	4	5.333
smf06sp2	0.957	8	6	7.250	0.957	8	2	3.333	2.309	6	5	7.000
smf06sp3	0.577	8	7	7.250	0.500	8	4	5.000	1.000	6	5	7.000
smf07sp1	1.633	9	6	7.500	1.291	9	2	3.250	1.258	5	5	6.667
smf08sp1	1.304	7	4	7.000	1.732	8	2	4.750	2.217	7	6	7.750
smf08sp2	1.673	8	7	7.600	0.548	8	3	5.400	1.517	7	6	7.500
smf08sp3	1.732	9	4	7.000	2.000	8	4	6.000	1.732	7	7	7.667
smf09sp1	1.817	6	2	3.800	1.483	6	2	4.000	1.871	6	7	7.800
smf10sp1	0.837	7	7	7.000	0.000	7	2	4.500	1.732	6	3	5.000
smf10sp2	1.000	7	5	6.500	1.000	7	5	5.333	0.577	6	3	5.000
smf11sp1	1.506	8	4	6.500	1.378	8	2	4.833	2.041	8	6	7.400
smf11sp2	0.000	9	9	9.000	0.000	9	7	8.250	0.957	9	8	8.667

space	E35StdDev	E35Max	E36Min	E36Mean	E36StdDev	E36Max	E37Min	E37Mean	E37StdDev	E37Max	E38Min	E38Mean
nyc01sp1	1.789	8	2	7.000	2.683	9	2	7.000	2.683	9	2	5.333
nyc01sp2	1.366	8	4	6.333	1.366	8	4	6.500	1.378	8	3	4.333
nyc02sp1	1.574	6	6	7.714	1.113	9	6	8.000	1.000	9	5	6.857
nyc02sp2	1.069	7	4	6.857	1.574	9	4	7.286	1.604	9	5	5.857
nyc04sp1	2.289	9	2	4.000	1.826	7	2	3.857	1.215	5	1	2.714
nyc04sp2	2.268	9	2	4.833	2.041	7	2	4.833	2.041	7	1	3.333
nyc05sp1	1.069	8	4	7.143	1.464	8	4	7.286	1.604	9	4	5.857
nyc05sp2	1.799	8	4	6.833	1.472	8	4	6.833	1.472	8	4	5.667
nyc08sp1	0.516	5	2	2.833	0.408	3	1	2.833	0.983	4	1	2.500
nyc08sp2	0.707	5	1	2.000	1.414	3	1	2.000	1.414	3	1	2.000
nyc09sp1	2.160	9	8	8.500	0.577	9	8	8.500	0.577	9	6	6.750
sea01sp1	1.291	7	4	6.000	1.915	8	3	5.714	2.215	8	2	4.571
sea01sp2	1.512	8	2	5.857	2.268	9	2	5.857	2.268	9	2	3.857
sea01sp3	1.676	8	7	8.143	0.690	9	8	8.286	0.488	9	4	5.857
sea02sp1	1.773	9	8	8.429	0.535	9	8	8.429	0.535	9	5	7.000
sea02sp2	0.900	8	2	3.286	2.138	8	2	3.143	1.773	7	1	2.000
sea02sp3	1.618	8	6	7.429	0.787	8	7	7.571	0.535	8	4	5.000
sea03sp1	1.254	5	7	8.429	0.787	9	7	8.143	0.900	9	4	6.429
sea03sp2	1.761	8	8	8.714	0.488	9	8	8.571	0.535	9	4	5.571
sea04sp1	2.422	8	8	8.500	0.548	9	7	8.333	0.816	9	5	5.667
sea04sp2	1.472	7	8	8.833	0.408	9	8	8.667	0.516	9	6	6.833
sea06sp1	1.722	9	2	4.500	1.517	6	4	5.500	1.049	7	2	3.167
sea06sp2	1.366	9	5	7.167	1.169	8	5	7.500	1.225	8	3	5.500
sea06sp3	1.378	9	8	8.833	0.408	9	8	8.833	0.408	9	8	8.500
sea06sp4	3.240	9	9	9.000	0.000	9	9	9.000	0.000	9	7	8.200
sea07sp1	1.941	8	4	5.833	1.722	8	4	5.833	1.722	8	2	3.667
sea07sp2	1.169	8	6	7.333	0.816	8	6	7.333	0.816	8	3	6.167
sea07sp3	1.265	8	8	8.667	0.516	9	8	8.667	0.516	9	5	6.833
sfo01sp1	0.000	2	6	6.667	0.577	7	6	6.667	0.577	7	4	5.333
sfo01sp2	1.732	5	6	6.667	0.577	7	6	6.667	0.577	7	4	5.000
sfo01sp4	0.577	4	7	7.667	0.577	8	7	7.333	0.577	8	5	6.333
sfo02sp1	1.732	6	4	5.750	1.708	8	4	5.000	1.414	7	3	4.000
sfo02sp3	1.000	5	3	3.000	0.000	3	3	3.000	0.000	3	2	2.000
sfo04sp1	1.291	6	5	5.750	0.957	7	5	5.750	0.957	7	3	4.750
sfo04sp2	0.816	7	3	4.250	1.258	6	3	4.250	1.258	6	2	3.000
sfo05sp1	0.707	8	2	3.400	1.140	5	2	3.400	1.140	5	2	2.800
sfo05sp2	1.342	8	1	2.200	1.095	4	1	2.000	0.707	3	1	1.400
sfo05sp3	0.894	9	3	3.400	0.894	5	3	3.200	0.447	4	1	2.000
sfo05sp4	1.000	8	3	4.200	1.095	5	3	3.800	0.837	5	3	3.000
sfo06sp1	2.302	8	8	8.600	0.548	9	8	8.600	0.548	9	4	6.600
sfo06sp2	1.414	8	8	8.500	0.577	9	8	8.500	0.577	9	5	7.250
sfo07sp1	1.342	6	7	8.200	0.837	9	7	8.200	0.837	9	4	6.800
smf02sp1	NA	#NAME?	1	1.800	0.837	3	1	2.000	0.707	3	1	1.000
smf03sp1	NA	#NAME?	9	9.000	0.000	9	9	9.000	0.000	9	7	8.200
smf03sp2	NA	#NAME?	8	8.600	0.548	9	8	8.400	0.548	9	5	6.200
smf04sp1	1.414	8	3	5.500	2.082	8	3	5.500	2.517	9	2	3.500
smf04sp2	1.414	8	3	5.000	2.345	9	3	5.000	2.550	9	1	2.800
smf04sp3	1.414	8	8	8.600	0.548	9	7	8.200	0.837	9	5	6.600
smf05sp1	2.380	6	8	8.250	0.500	9	7	7.500	0.577	8	4	5.000
smf06sp1	1.155	6	8	8.750	0.500	9	8	8.750	0.500	9	6	7.500
smf06sp2	1.732	8	9	9.000	0.000	9	9	9.000	0.000	9	7	7.250
smf06sp3	1.732	8	8	8.500	0.577	9	8	8.500	0.577	9	6	7.000
smf07sp1	2.082	9	4	6.500	2.082	9	4	6.500	2.082	9	2	4.750
smf08sp1	1.258	9	2	3.800	1.483	6	2	4.200	1.924	7	1	2.800
smf08sp2	1.000	8	3	3.600	0.894	5	3	3.800	1.304	6	2	2.400
smf08sp3	0.577	8	2	3.250	2.500	7	2	3.500	2.380	7	1	2.250
smf09sp1	0.447	8	4	5.600	1.140	7	4	5.600	1.140	7	3	4.400
smf10sp1	1.633	7	3	6.600	2.302	9	4	5.800	1.483	8	3	4.800
smf10sp2	1.633	7	1	1.200	0.447	2	1	1.400	0.548	2	1	1.200
smf11sp1	1.342	9	7	8.000	0.894	9	6	7.667	0.816	8	5	6.000
smf11sp2	0.577	9	2	5.500	2.646	8	2	4.500	2.517	8	1	3.000

space	E38StdDev	E38Max	E39Min	E39Mean	E39StdDev	E39Max	E40Min	E40Mean	E40StdDev	E40Max	E41Min	E41Mean
nyc01sp1	2.338	8	2	6.000	2.530	9	2	6.333	2.503	9	2	6.167
nyc01sp2	1.633	7	4	6.167	1.472	8	4	6.167	1.169	7	4	6.333
nyc02sp1	1.676	9	3	6.143	1.574	7	3	6.286	1.496	7	3	6.286
nyc02sp2	1.069	7	5	7.429	1.272	9	4	7.286	1.604	9	4	7.143
nyc04sp1	1.254	4	1	3.714	2.289	8	1	3.429	1.397	5	1	3.429
nyc04sp2	1.862	6	1	3.333	1.506	5	1	3.333	1.366	5	1	3.333
nyc05sp1	2.116	9	5	6.429	1.512	9	4	6.571	1.813	9	4	6.571
nyc05sp2	1.366	7	4	6.000	1.549	8	4	6.167	1.472	8	4	6.000
nyc08sp1	1.049	4	2	2.667	0.516	3	2	2.500	0.548	3	2	2.500
nyc08sp2	1.414	3	2	3.000	1.414	4	2	3.000	1.414	4	2	2.500
nyc09sp1	0.500	7	7	8.250	0.957	9	7	8.000	0.816	9	7	8.000
sea01sp1	2.440	8	3	5.571	2.149	8	3	5.571	2.149	8	3	5.571
sea01sp2	1.773	7	4	5.714	1.380	7	4	4.857	1.069	6	4	4.857
sea01sp3	1.464	8	4	7.143	1.574	9	4	7.000	1.528	9	3	6.857
sea02sp1	1.291	9	5	7.286	1.380	9	5	7.143	1.345	9	5	7.143
sea02sp2	1.414	5	2	4.286	1.890	8	2	3.857	1.952	8	2	3.857
sea02sp3	1.155	7	6	7.571	0.787	8	6	7.143	0.690	8	6	7.286
sea03sp1	1.618	9	4	6.857	1.773	9	3	6.143	1.952	9	3	6.143
sea03sp2	1.272	7	7	8.571	0.787	9	6	7.714	0.951	9	6	7.714
sea04sp1	1.033	7	8	8.500	0.548	9	6	7.800	1.095	9	6	7.800
sea04sp2	0.753	8	7	8.500	0.837	9	6	7.500	1.049	9	6	7.500
sea06sp1	1.169	5	4	5.667	1.366	7	4	5.167	0.983	6	4	5.167
sea06sp2	1.378	7	4	6.500	1.643	8	5	6.500	1.225	8	5	6.500
sea06sp3	0.548	9	6	8.000	1.549	9	6	7.667	1.366	9	6	7.667
sea06sp4	1.095	9	9	9.000	0.000	9	9	9.000	0.000	9	9	9.000
sea07sp1	1.366	6	5	5.833	0.408	6	5	5.500	0.548	6	5	5.500
sea07sp2	1.722	8	4	6.333	1.751	9	3	5.333	1.751	8	3	5.333
sea07sp3	1.169	8	7	8.000	0.894	9	7	7.833	0.753	9	7	7.667
sfo01sp1	1.155	6	5	6.667	1.528	8	5	6.000	1.000	7	5	6.000
sfo01sp2	1.000	6	6	6.667	0.577	7	6	6.000	0.000	6	6	6.000
sfo01sp4	1.155	7	8	8.000	0.000	8	7	7.667	0.577	8	7	7.667
sfo02sp1	1.414	6	4	5.750	1.708	8	4	5.250	1.893	8	4	5.250
sfo02sp3	0.000	2	3	3.000	0.000	3	2	2.750	0.500	3	2	2.750
sfo04sp1	1.258	6	4	5.500	1.291	7	3	4.750	1.708	7	3	4.750
sfo04sp2	1.414	5	4	5.000	0.816	6	4	5.500	1.291	7	4	5.500
sfo05sp1	0.837	4	2	3.600	1.140	5	2	2.800	0.837	4	2	2.600
sfo05sp2	0.548	2	1	2.400	1.140	4	1	2.000	0.707	3	1	2.000
sfo05sp3	1.000	3	3	4.000	1.414	6	2	3.400	1.140	5	2	3.400
sfo05sp4	0.000	3	3	4.000	1.000	5	3	3.600	0.548	4	3	3.600
sfo06sp1	1.673	8	8	8.600	0.548	9	7	8.200	0.837	9	7	8.200
sfo06sp2	1.706	9	8	8.500	0.577	9	7	8.000	0.816	9	7	8.000
sfo07sp1	1.643	8	7	8.000	0.707	9	7	7.500	1.000	9	7	7.500
smf02sp1	0.000	1	1	2.000	0.707	3	1	2.000	0.707	3	1	2.000
smf03sp1	0.837	9	9	9.000	0.000	9	Inf	NA	NA	#NAME?	7	8.400
smf03sp2	0.837	7	8	8.600	0.548	9	Inf	NA	NA	#NAME?	7	8.200
smf04sp1	1.291	5	3	5.500	2.082	8	3	5.750	2.062	8	2	5.500
smf04sp2	1.643	5	3	5.000	2.345	9	3	5.200	2.387	9	2	5.000
smf04sp3	1.140	8	8	8.600	0.548	9	8	8.600	0.548	9	8	8.600
smf05sp1	0.816	6	8	8.250	0.500	9	7	8.000	0.816	9	7	8.000
smf06sp1	1.291	9	8	8.750	0.500	9	8	8.500	0.577	9	8	8.500
smf06sp2	0.500	8	9	9.000	0.000	9	9	9.000	0.000	9	9	9.000
smf06sp3	0.816	8	8	8.500	0.577	9	8	8.500	0.577	9	8	8.500
smf07sp1	2.062	7	6	7.500	1.291	9	6	7.500	1.291	9	6	7.500
smf08sp1	1.095	4	6	6.800	1.095	8	5	7.000	1.414	8	5	6.800
smf08sp2	0.548	3	5	6.400	0.894	7	5	6.000	1.000	7	5	5.800
smf08sp3	2.500	6	5	6.250	1.258	8	5	6.000	1.414	8	5	6.000
smf09sp1	1.140	6	5	6.000	0.707	7	5	6.000	1.000	7	4	5.600
smf10sp1	1.304	6	3	6.600	2.302	9	3	6.200	2.168	9	3	5.800
smf10sp2	0.447	2	1	1.400	0.548	2	1	1.400	0.548	2	1	1.400
smf11sp1	0.894	7	7	8.000	0.894	9	7	7.833	0.753	9	7	7.833
smf11sp2	2.160	6	3	5.750	2.217	8	2	5.500	2.646	8	2	5.500

space	E41StdDev	E41Max	E42Min	E42Mean	E42StdDev	E42Max	E43Min	E43Mean	E43StdDev	E43Max	E44Min	E44Mean
nyc01sp1	2.483	9	2	5.667	2.422	9	5	7.333	1.633	9	5	7.333
nyc01sp2	1.211	7	2	5.500	1.871	7	3	5.500	2.258	9	4	6.000
nyc02sp1	1.496	7	4	5.857	1.069	7	4	6.000	1.915	8	3	5.571
nyc02sp2	1.464	8	4	6.286	1.380	8	3	6.857	2.410	9	3	6.857
nyc04sp1	1.618	5	1	3.429	1.813	6	4	7.429	1.618	9	3	6.714
nyc04sp2	1.366	5	1	3.333	1.633	5	4	6.500	2.074	9	4	6.500
nyc05sp1	1.813	9	3	6.286	2.138	9	4	7.286	1.799	9	4	6.857
nyc05sp2	1.673	8	3	6.167	2.483	8	5	7.500	1.378	9	5	7.500
nyc08sp1	0.548	3	2	2.500	0.548	3	4	4.000	0.000	4	4	5.000
nyc08sp2	0.707	3	2	2.000	0.000	2	4	4.000	0.000	4	4	4.500
nyc09sp1	0.816	9	6	7.000	0.816	8	3	6.750	2.500	8	3	6.750
sea01sp1	2.149	8	3	4.857	1.864	8	2	6.857	2.795	9	4	7.429
sea01sp2	1.069	6	2	3.429	0.976	5	3	4.833	2.137	8	4	5.667
sea01sp3	1.864	9	2	6.143	2.116	8	4	6.500	1.761	8	5	7.333
sea02sp1	1.345	9	3	6.143	2.116	9	3	5.000	1.826	8	3	4.857
sea02sp2	1.952	8	1	2.714	1.976	7	4	6.286	1.976	9	4	6.286
sea02sp3	0.756	8	4	5.571	1.397	8	2	5.286	2.138	8	2	5.286
sea03sp1	1.952	9	2	4.286	2.812	9	3	6.000	1.826	8	3	6.143
sea03sp2	0.951	9	4	6.429	1.988	9	7	8.000	0.816	9	8	8.571
sea04sp1	1.095	9	5	6.600	1.140	8	3	6.833	2.041	9	3	7.333
sea04sp2	1.049	9	3	5.500	1.975	9	4	7.500	1.871	9	6	7.833
sea06sp1	0.983	6	3	4.000	0.894	5	3	6.000	2.280	9	2	6.000
sea06sp2	1.225	8	5	5.500	0.548	6	6	7.833	1.169	9	3	7.333
sea06sp3	1.366	9	3	6.833	2.317	9	3	6.833	2.137	9	2	6.333
sea06sp4	0.000	9	7	8.400	0.894	9	1	4.200	3.271	9	1	5.800
sea07sp1	0.548	6	4	5.167	1.169	7	4	6.333	2.066	9	3	6.333
sea07sp2	1.751	8	1	4.000	2.098	7	4	7.167	1.722	9	3	6.667
sea07sp3	0.816	9	6	6.667	0.816	8	5	7.333	1.366	9	5	7.333
sfo01sp1	1.000	7	4	5.333	1.155	6	6	7.000	1.000	8	6	7.000
sfo01sp2	0.000	6	4	4.667	0.577	5	6	6.333	0.577	7	6	6.333
sfo01sp4	0.577	8	6	6.667	0.577	7	7	7.667	0.577	8	8	8.000
sfo02sp1	1.893	8	3	4.500	1.732	7	4	5.500	1.732	7	5	6.000
sfo02sp3	0.500	3	2	2.250	0.500	3	2	3.000	0.816	4	3	3.500
sfo04sp1	1.708	7	2	4.000	1.826	6	5	6.500	1.291	8	5	6.250
sfo04sp2	1.291	7	3	5.000	1.633	7	3	6.000	2.160	8	3	6.500
sfo05sp1	0.548	3	2	3.000	0.707	4	3	7.000	2.345	9	5	7.200
sfo05sp2	0.707	3	1	2.000	0.707	3	4	6.800	2.588	9	4	7.000
sfo05sp3	1.140	5	2	3.000	1.225	5	3	5.600	2.302	8	3	5.800
sfo05sp4	0.548	4	3	3.200	0.447	4	3	4.400	1.140	6	4	5.600
sfo06sp1	0.837	9	6	7.400	1.140	9	4	5.200	1.304	7	7	8.400
sfo06sp2	0.816	9	6	7.500	1.291	9	3	6.250	2.217	8	7	8.000
sfo07sp1	1.000	9	6	7.200	1.095	9	2	6.400	2.510	8	2	6.600
smf02sp1	0.707	3	1	2.400	1.517	4	2	5.000	3.240	9	2	5.400
smf03sp1	0.894	9	6	7.000	0.707	8	3	7.400	2.510	9	7	8.400
smf03sp2	0.837	9	5	7.000	1.414	8	5	7.800	1.643	9	5	8.000
smf04sp1	2.517	8	2	5.000	2.582	8	7	7.750	0.957	9	7	8.000
smf04sp2	2.646	9	2	4.400	3.050	9	8	8.200	0.447	9	6	7.800
smf04sp3	0.548	9	7	8.200	0.837	9	7	7.600	0.894	9	6	7.800
smf05sp1	0.816	9	6	6.750	0.957	8	7	7.750	0.500	8	8	8.250
smf06sp1	0.577	9	6	7.750	1.258	9	3	6.500	2.380	8	3	6.750
smf06sp2	0.000	9	8	8.750	0.500	9	8	8.500	0.577	9	8	8.500
smf06sp3	0.577	9	7	7.750	0.957	9	9	9.000	0.000	9	7	8.500
smf07sp1	1.291	9	4	6.250	1.708	8	8	8.250	0.500	9	7	8.000
smf08sp1	1.304	8	4	6.200	1.643	8	8	8.800	0.447	9	7	8.200
smf08sp2	0.837	7	4	5.200	1.304	7	5	7.200	1.483	9	6	7.400
smf08sp3	1.414	8	4	5.750	2.062	8	7	8.250	0.957	9	7	8.000
smf09sp1	1.140	7	4	6.000	1.414	7	7	7.800	0.837	9	7	7.800
smf10sp1	2.387	9	3	5.600	1.817	8	1	1.800	0.837	3	2	3.600
smf10sp2	0.548	2	1	1.200	0.447	2	1	3.400	2.702	8	3	5.800
smf11sp1	0.753	9	6	7.000	0.894	8	7	7.667	0.816	9	7	8.200
smf11sp2	2.646	8	1	4.750	2.986	8	9	9.000	0.000	9	9	9.000

space	E44StdDev	E44Max	E45Min	E45Mean	E45StdDev	E45Max	E46Min	E46Mean	E46StdDev	E46Max	E47Min	E47Mean
nyc01sp1	1.633	9	4	7.500	2.074	9	5	6.833	1.602	9	5	6.667
nyc01sp2	1.897	9	5	6.500	1.517	9	3	4.833	1.472	7	3	4.833
nyc02sp1	1.902	8	4	6.857	1.773	9	2	4.571	1.397	6	2	3.857
nyc02sp2	2.410	9	5	7.857	1.464	9	4	6.000	1.414	8	4	5.857
nyc04sp1	2.289	9	7	7.857	0.690	9	3	5.714	2.498	9	3	6.000
nyc04sp2	2.074	9	5	7.333	1.366	9	3	5.167	2.639	9	3	5.500
nyc05sp1	1.676	9	4	7.429	1.813	9	3	5.429	1.813	8	3	5.429
nyc05sp2	1.378	9	5	8.000	1.549	9	3	4.333	1.033	6	1	4.333
nyc08sp1	0.632	6	5	5.833	1.602	9	3	4.000	0.632	5	4	4.000
nyc08sp2	0.707	5	5	7.000	2.828	9	3	4.000	1.414	5	4	4.000
nyc09sp1	2.500	8	7	8.000	0.816	9	3	4.500	1.915	7	4	5.750
sea01sp1	1.902	9	6	8.000	1.155	9	6	7.857	1.069	9	4	6.714
sea01sp2	2.066	9	7	7.833	0.983	9	2	3.667	1.366	6	2	4.333
sea01sp3	1.633	9	6	8.333	1.211	9	3	6.000	2.309	9	3	5.429
sea02sp1	1.574	7	6	7.714	0.951	9	2	4.143	1.773	6	2	4.429
sea02sp2	1.704	9	5	7.286	1.496	9	3	5.429	1.718	8	3	5.714
sea02sp3	2.138	8	4	6.714	1.604	8	1	4.571	2.440	8	1	5.000
sea03sp1	1.773	8	6	7.143	0.900	8	1	4.286	1.976	7	2	5.286
sea03sp2	0.535	9	8	8.714	0.488	9	5	8.143	1.464	9	5	7.714
sea04sp1	2.251	9	7	8.167	0.753	9	2	5.000	2.530	8	3	6.333
sea04sp2	1.169	9	8	8.333	0.516	9	4	6.167	1.472	8	4	6.833
sea06sp1	2.366	9	4	7.000	1.673	9	2	4.500	2.168	7	2	5.833
sea06sp2	2.251	9	6	8.000	1.095	9	2	5.333	2.658	8	3	6.333
sea06sp3	2.503	9	5	7.667	1.506	9	2	4.333	2.251	8	3	4.667
sea06sp4	3.114	9	4	7.200	1.924	9	1	4.000	3.162	9	1	3.600
sea07sp1	2.160	9	5	7.500	1.643	9	6	6.833	0.983	8	6	6.667
sea07sp2	2.066	9	2	6.833	2.639	9	2	3.833	2.229	8	3	5.000
sea07sp3	1.366	9	7	8.333	0.816	9	6	8.333	1.211	9	5	8.000
sfo01sp1	1.000	8	6	7.667	1.528	9	4	5.333	1.155	6	4	5.667
sfo01sp2	0.577	7	6	7.000	1.000	8	5	6.000	1.000	7	6	7.000
sfo01sp4	0.000	8	5	7.000	1.732	8	7	7.333	0.577	8	7	7.667
sfo02sp1	0.816	7	5	6.750	1.708	9	4	5.750	2.062	8	3	5.000
sfo02sp3	0.577	4	2	3.500	1.291	5	2	3.250	0.957	4	2	3.000
sfo04sp1	0.957	7	5	6.750	1.258	8	3	3.500	0.577	4	3	3.750
sfo04sp2	2.380	8	8	8.250	0.500	9	4	5.250	1.258	7	3	4.750
sfo05sp1	1.643	9	6	8.000	1.225	9	3	6.200	2.280	9	2	5.600
sfo05sp2	2.345	9	4	7.200	2.490	9	4	6.800	2.588	9	4	6.800
sfo05sp3	2.280	8	5	6.800	1.643	9	3	5.400	1.949	8	2	4.600
sfo05sp4	1.140	7	6	7.200	1.095	8	4	5.600	1.140	7	3	5.800
sfo06sp1	0.894	9	8	8.600	0.548	9	5	6.400	1.342	8	4	5.200
sfo06sp2	0.816	9	8	8.500	0.577	9	5	7.250	1.500	8	4	6.250
sfo07sp1	2.608	8	4	7.000	2.000	8	3	6.200	1.924	8	3	5.800
smf02sp1	2.966	9	1	5.000	3.808	9	2	4.000	2.449	8	2	5.000
smf03sp1	0.894	9	9	9.000	0.000	9	Inf	NA	NA	#NAME?	3	7.400
smf03sp2	1.732	9	7	8.600	0.894	9	Inf	NA	NA	#NAME?	5	7.800
smf04sp1	0.816	9	7	8.500	1.000	9	6	7.000	0.816	8	7	7.250
smf04sp2	1.304	9	6	8.400	1.342	9	5	7.000	1.414	8	7	8.000
smf04sp3	1.095	9	6	8.200	1.304	9	7	7.800	0.837	9	7	7.600
smf05sp1	0.500	9	8	8.500	0.577	9	7	7.750	0.500	8	7	7.750
smf06sp1	2.630	9	7	8.000	0.816	9	2	6.750	3.202	9	2	6.000
smf06sp2	0.577	9	9	9.000	0.000	9	7	8.000	0.816	9	8	8.500
smf06sp3	1.000	9	9	9.000	0.000	9	4	6.500	1.732	8	4	6.500
smf07sp1	0.816	9	8	8.250	0.500	9	4	6.250	1.708	8	4	6.500
smf08sp1	0.837	9	8	8.600	0.548	9	4	5.800	1.643	8	4	6.400
smf08sp2	1.140	9	4	6.800	1.924	9	5	6.200	1.304	8	4	5.800
smf08sp3	0.816	9	7	8.000	0.816	9	4	6.000	1.633	8	4	6.000
smf09sp1	0.837	9	6	7.800	1.095	9	2	3.600	1.517	5	2	4.200
smf10sp1	1.517	5	2	5.400	2.191	8	1	2.000	1.000	3	1	2.000
smf10sp2	2.280	8	3	6.600	2.510	9	1	3.200	2.775	8	1	3.000
smf11sp1	0.837	9	8	8.600	0.548	9	5	7.400	1.517	9	7	7.600
smf11sp2	0.000	9	9	9.000	0.000	9	9	9.000	0.000	9	9	9.000

space	E47StdDev	E47Max	E48Min	E48Mean	E48StdDev	E48Max	E49Min	E49Mean	E49StdDev	E49Max	EAMin	EAMean
nyc01sp1	1.633	9	3	6.500	2.168	9	2	6.333	2.658	9	6	7.417
nyc01sp2	0.983	6	3	4.667	1.211	6	3	5.000	1.673	7	3	5.167
nyc02sp1	1.574	6	2	4.286	1.254	6	2	4.429	1.272	6	5.5	6.929
nyc02sp2	1.345	8	4	6.000	1.414	8	5	6.571	1.272	8	5.5	7.000
nyc04sp1	2.309	9	3	5.714	2.498	9	3	5.429	2.760	9	6.5	6.929
nyc04sp2	2.429	9	3	5.167	2.639	9	2	4.833	2.927	9	5.5	6.571
nyc05sp1	1.718	8	3	5.286	1.604	7	3	5.143	1.952	8	4	6.643
nyc05sp2	1.751	6	3	4.333	1.366	7	3	4.333	1.633	7	3.5	5.929
nyc08sp1	0.000	4	3	4.000	0.632	5	2	2.500	0.548	3	3	4.333
nyc08sp2	0.000	4	3	4.000	1.414	5	2	2.500	0.707	3	3.5	4.750
nyc09sp1	2.062	8	3	4.500	1.915	7	2	3.750	2.872	8	7	7.750
sea01sp1	2.059	9	4	7.286	1.799	9	3	7.143	2.035	9	4	6.214
sea01sp2	1.751	7	2	3.500	1.378	6	1	2.667	1.633	5	5	6.429
sea01sp3	1.902	8	3	6.000	2.309	9	2	6.429	2.760	9	5.5	7.214
sea02sp1	1.718	7	2	3.857	1.464	6	1	2.857	1.574	5	7	8.000
sea02sp2	1.890	8	3	5.143	1.464	7	2	3.571	2.149	7	3.5	4.214
sea02sp3	2.828	8	1	4.571	2.440	8	1	2.714	1.496	5	6	6.500
sea03sp1	2.289	8	1	4.286	1.976	7	1	2.286	1.604	5	2.5	5.143
sea03sp2	1.380	9	5	8.143	1.464	9	4	7.857	2.035	9	2.5	7.000
sea04sp1	2.338	9	2	4.667	2.658	8	1	4.833	2.787	8	5	6.333
sea04sp2	1.722	9	4	6.167	1.472	8	3	3.667	1.211	6	6.5	7.417
sea06sp1	2.317	8	2	4.500	2.168	7	3	4.000	1.265	6	6.5	7.500
sea06sp2	1.966	8	2	5.333	2.658	8	3	5.500	1.871	8	7	7.833
sea06sp3	1.966	8	2	4.333	2.251	8	1	4.000	2.966	8	8	8.667
sea06sp4	3.435	9	1	4.000	3.162	9	1	4.200	3.114	9	2	4.700
sea07sp1	0.516	7	6	6.667	0.816	8	6	6.833	1.169	9	4	5.833
sea07sp2	2.098	8	2	3.833	2.229	8	1	2.500	2.510	7	3.5	6.000
sea07sp3	1.549	9	6	8.333	1.211	9	6	8.333	1.211	9	7	7.917
sfo01sp1	1.528	7	4	5.333	1.155	6	4	5.333	1.528	7	5	5.167
sfo01sp2	1.000	8	5	6.000	1.000	7	3	4.667	1.528	6	5	5.500
sfo01sp4	0.577	8	7	7.333	0.577	8	6	7.000	1.000	8	6	6.667
sfo02sp1	1.826	7	4	5.750	2.062	8	4	5.750	2.062	8	3	3.833
sfo02sp3	0.816	4	2	3.000	0.816	4	2	3.750	1.500	5	2.5	2.875
sfo04sp1	0.500	4	3	3.500	0.577	4	2	3.000	1.155	4	7	7.375
sfo04sp2	1.500	6	4	5.250	1.258	7	4	5.750	1.500	7	5	5.750
sfo05sp1	2.881	8	3	6.600	2.191	9	4	6.400	1.949	9	2	4.400
sfo05sp2	2.588	9	4	6.800	2.588	9	4	7.000	2.345	9	2	3.600
sfo05sp3	2.302	8	3	5.400	1.949	8	3	6.000	2.000	8	4	5.700
sfo05sp4	1.789	7	4	5.600	1.140	7	2	5.200	2.387	8	3	4.700
sfo06sp1	1.304	7	5	6.400	1.342	8	5	7.200	1.304	8	6	7.000
sfo06sp2	1.708	8	5	7.250	1.500	8	6	7.750	1.258	9	7	7.625
sfo07sp1	2.168	8	3	6.200	1.924	8	3	6.600	2.074	8	5	7.400
smf02sp1	3.240	9	2	4.000	2.449	8	1	3.400	2.702	8	3	4.500
smf03sp1	2.510	9	5	6.800	1.095	8	3	5.800	2.588	8	8.5	8.800
smf03sp2	1.643	9	6	8.200	1.304	9	4	7.600	2.074	9	7	8.200
smf04sp1	0.500	8	6	7.000	0.816	8	4	5.500	1.291	7	3	5.700
smf04sp2	0.707	9	5	7.400	1.517	9	4	6.600	2.074	9	4	6.200
smf04sp3	0.894	9	7	7.400	0.548	8	5	7.000	1.581	9	7.5	8.000
smf05sp1	0.500	8	7	7.750	0.500	8	8	8.250	0.500	9	5	6.875
smf06sp1	2.828	8	2	6.750	3.202	9	3	7.250	2.872	9	3.5	7.125
smf06sp2	0.577	9	7	8.250	0.957	9	6	7.000	1.155	8	7.5	8.250
smf06sp3	1.732	8	4	6.500	1.732	8	4	6.250	1.708	8	6.5	7.625
smf07sp1	1.732	8	4	6.250	1.708	8	4	6.500	1.915	8	6.5	7.000
smf08sp1	1.673	8	4	6.200	1.643	8	3	4.800	1.304	6	6	7.200
smf08sp2	1.304	7	4	5.400	1.140	7	4	4.000	0.000	4	3.5	6.100
smf08sp3	1.633	8	4	6.000	1.633	8	4	6.250	2.217	9	5	6.600
smf09sp1	1.304	5	1	3.600	1.673	5	1	2.600	2.074	6	2.5	5.100
smf10sp1	1.000	3	1	2.000	1.000	3	1	2.800	1.643	4	1	1.900
smf10sp2	2.915	8	1	3.200	2.775	8	1	3.200	2.280	7	1	1.200
smf11sp1	0.894	9	5	7.400	1.517	9	3	7.200	2.387	9	5.5	7.583
smf11sp2	0.000	9	9	9.000	0.000	9	9	9.000	0.000	9	7	7.375

space	EAStdDev	EAMax	EBMin	EBMean	EBStdDev	EBMax	ECMin	ECMean	ECStdDev	ECMax	EDMin	EDMean
nyc01sp1	1.021	9	8	8.333	0.408	9	Inf	NA	NA	#NAME?	3	6.000
nyc01sp2	1.472	7	1	3.167	1.506	5	5	6.000	0.894	7	1	4.500
nyc02sp1	0.787	8	5.5	7.143	1.029	9	6	7.286	0.951	9	3.5	6.786
nyc02sp2	0.957	8	3	5.857	1.725	8.5	6	7.571	1.134	9	3.5	6.714
nyc04sp1	0.450	7.5	7	7.786	0.859	9	4	6.000	1.732	9	2.5	3.714
nyc04sp2	0.673	7.5	6.5	7.714	0.951	9	3	5.571	1.902	9	2.5	4.286
nyc05sp1	1.520	8.5	3	6.286	1.912	9	4	5.857	1.773	8	4	6.286
nyc05sp2	1.456	7.5	3.5	5.857	1.626	8	2	4.500	1.871	7	2.5	6.071
nyc08sp1	1.633	7.5	4	5.000	0.632	6	3	3.833	0.753	5	1	2.333
nyc08sp2	1.768	6	4	4.250	0.354	4.5	4	4.000	0.000	4	1	2.250
nyc09sp1	0.500	8	8	8.750	0.500	9	Inf	NA	NA	#NAME?	7	7.500
sea01sp1	1.318	8	4.5	7.000	1.472	8.5	2	6.000	2.309	9	3.5	6.071
sea01sp2	1.272	8	8	8.571	0.535	9	4	6.857	1.676	8	2	5.071
sea01sp3	0.906	8	7.5	8.214	0.636	9	5	6.857	1.069	8	4	7.000
sea02sp1	0.577	9	5	7.214	1.380	8.5	5	6.000	0.816	7	5	7.286
sea02sp2	0.809	5.5	2	5.214	1.933	8	3	5.857	1.676	7	1.5	2.357
sea02sp3	0.764	8	3.5	5.786	1.629	8	1	4.857	2.340	7	4.5	5.571
sea03sp1	1.547	6.5	6.5	7.500	0.707	8.5	1	3.714	2.059	7	4.5	6.643
sea03sp2	2.141	9	1.5	3.750	2.062	5.5	1	2.333	2.309	5	6	7.286
sea04sp1	1.211	8	3	5.000	1.897	8	1	3.000	2.160	6	6.5	7.250
sea04sp2	0.665	8	6.5	7.750	0.822	9	6	7.167	0.753	8	6	7.750
sea06sp1	0.632	8	4.5	7.667	1.941	9	3	6.167	1.835	8	2	3.667
sea06sp2	0.683	9	7.5	8.500	0.775	9	3	6.167	1.835	8	3	5.600
sea06sp3	0.516	9	9	9.000	0.000	9	7	7.667	0.816	9	6	8.417
sea06sp4	1.718	6	1	1.000	0.000	1	1	1.000	NA	1	5	7.100
sea07sp1	1.633	8	5	7.667	1.722	9	5	7.167	1.722	9	2	4.833
sea07sp2	1.581	8	6.5	7.167	0.408	7.5	1	4.333	2.160	7	2.5	6.417
sea07sp3	0.585	8.5	6.5	8.250	0.935	9	Inf	NA	NA	#NAME?	6.5	8.000
sfo01sp1	0.289	5.5	1.5	1.833	0.289	2	1	1.000	NA	1	3	3.833
sfo01sp2	0.500	6	5.5	6.167	0.577	6.5	4	5.333	1.528	7	4.5	5.333
sfo01sp4	0.577	7	6.5	6.833	0.577	7.5	5	6.333	1.155	7	6	6.667
sfo02sp1	1.041	5	3	3.500	0.707	4.5	1	2.750	1.258	4	3.5	5.375
sfo02sp3	0.479	3.5	1	2.625	1.377	4	2	2.500	1.000	4	2	2.375
sfo04sp1	0.479	8	8	8.000	0.000	8	3	5.500	1.732	7	4	5.750
sfo04sp2	0.957	7	6	7.250	1.258	9	4	5.500	1.000	6	2.5	4.500
sfo05sp1	1.917	7	2.5	3.500	1.000	5	2	3.800	1.095	5	2	2.900
sfo05sp2	2.074	7	1	2.200	1.643	5	Inf	NA	NA	#NAME?	1	1.500
sfo05sp3	1.204	7	4.5	5.400	0.822	6.5	5	6.000	1.732	8	1	3.800
sfo05sp4	1.483	7	3	3.500	0.500	4	3	4.400	1.673	7	1	3.100
sfo06sp1	1.000	8	2	5.375	2.394	7.5	1	1.000	NA	1	6.5	7.700
sfo06sp2	0.629	8.5	1	1.000	NA	1	1	1.000	NA	1	8	8.000
sfo07sp1	1.517	9	5.5	6.500	1.225	8	2	4.400	1.817	7	6.5	7.200
smf02sp1	1.768	7.5	3.5	5.300	2.308	9	Inf	NA	NA	#NAME?	1	1.600
smf03sp1	0.274	9	8	8.600	0.418	9	3	6.200	2.280	9	8	8.600
smf03sp2	0.837	9	7	8.400	0.822	9	1	3.400	2.191	7	5	7.200
smf04sp1	1.789	7.5	2	4.500	2.092	7.5	4	6.600	2.302	9	2	4.500
smf04sp2	1.483	8	3	5.600	1.949	7.5	5	6.800	1.304	8	3	4.900
smf04sp3	0.612	9	3.5	5.125	1.652	7	6	7.000	1.000	8	8	8.400
smf05sp1	1.931	9	1	1.333	0.577	2	1	1.000	NA	1	7.5	7.875
smf06sp1	2.428	8.5	7	8.125	0.854	9	7	8.000	0.816	9	8.5	8.625
smf06sp2	0.645	9	5	5.750	1.190	7.5	5	7.000	2.309	9	7.5	8.375
smf06sp3	0.750	8	7.5	7.625	0.250	8	5	6.750	1.708	9	7.5	8.250
smf07sp1	0.408	7.5	5	5.750	1.500	8	Inf	NA	NA	#NAME?	4	5.625
smf08sp1	1.255	9	6.5	7.800	0.837	8.5	3	5.000	2.345	8	4	5.800
smf08sp2	1.673	8	4	6.000	1.458	7.5	3	5.600	2.074	8	1	3.900
smf08sp3	1.557	8.5	7	7.600	0.652	8.5	3	5.400	2.408	8	2	4.600
smf09sp1	1.782	7	4.5	6.700	1.605	8	1	1.200	0.447	2	2.5	4.500
smf10sp1	0.894	3	1.5	2.300	0.570	3	2	4.000	1.581	6	1	4.625
smf10sp2	0.447	2	1.5	2.800	1.037	4	1	1.667	1.155	3	1	1.200
smf11sp1	1.068	8.5	6.5	7.800	0.837	8.5	6	7.500	1.049	9	7	7.833
smf11sp2	0.479	8	4.5	5.750	1.323	7.5	Inf	NA	NA	#NAME?	3.5	5.875

space	EDStdDev	EDMax	EEMin	EEMean	EEStdDev	EEMax	EFMin	EFMean	EFStdDev	EFMax	EGMin	EGMean
nyc01sp1	2.302	9	4.5	6.250	1.214	7.5	4	6.667	1.602	9	3	6.333
nyc01sp2	2.258	8	3	5.083	1.393	6.5	1	3.917	1.772	5.5	4	5.833
nyc02sp1	1.655	9	2.5	3.929	0.886	5	2	3.643	1.314	6	5	6.714
nyc02sp2	1.524	8	3.5	5.214	1.035	6.5	4	5.929	1.272	7.5	5	7.000
nyc04sp1	1.150	5.5	4	6.071	1.539	8.5	3.5	5.571	2.110	9	3	5.000
nyc04sp2	1.150	6	2.5	5.500	1.848	8.5	2	5.214	2.721	9	4	6.000
nyc05sp1	1.729	8	3.5	5.000	1.291	7	3	4.071	1.566	7.5	4	6.000
nyc05sp2	1.902	8	2.5	4.071	1.427	6.5	1.5	3.714	1.845	6.5	3	5.286
nyc08sp1	1.366	5	3.5	5.083	1.882	8	2	4.250	2.068	7	2	2.833
nyc08sp2	1.768	3.5	4	6.000	2.828	8	2.5	4.750	3.182	7	3	3.000
nyc09sp1	0.408	8	4	5.625	1.161	6.5	3	4.500	1.291	6	6	7.500
sea01sp1	1.967	8	5	6.083	1.158	7.5	4.5	6.500	1.949	9	4	6.000
sea01sp2	1.880	7.5	2.5	4.667	1.889	7	2	4.000	1.658	7	2	4.571
sea01sp3	1.893	9	4	5.400	1.949	8	1.5	4.786	2.628	8	5	7.000
sea02sp1	1.286	9	3.5	5.300	1.255	6.5	1.5	4.667	2.113	7.5	7	7.714
sea02sp2	0.627	3	4	6.000	1.414	7.5	3.5	5.143	1.314	6.5	2	3.000
sea02sp3	1.336	8	3	5.000	1.643	7.5	1.5	4.214	1.845	7	5	6.714
sea03sp1	1.520	9	1.5	3.583	1.800	6	1	3.357	2.231	6.5	4	6.000
sea03sp2	0.951	8.5	3	6.333	1.722	8	2.5	7.357	2.375	9	3	6.857
sea04sp1	0.987	8.5	2.5	5.700	2.308	7.5	3	5.417	1.934	7.5	6	7.333
sea04sp2	1.084	9	5	6.600	1.294	8	5.5	6.750	0.822	7.5	7	8.167
sea06sp1	1.538	5.5	4.5	5.900	0.962	7	2	5.083	1.934	7.5	3	4.833
sea06sp2	1.782	7.5	6	6.600	0.548	7.5	3.5	5.750	1.605	7.5	4	6.000
sea06sp3	1.201	9	2.5	3.800	1.440	6	2	4.500	2.121	7.5	7	8.000
sea06sp4	1.475	8.5	3	5.125	1.843	7.5	1	5.100	3.170	9	2	5.600
sea07sp1	1.602	6	4	5.700	1.440	7.5	3.5	5.667	1.693	8	3	4.667
sea07sp2	2.035	8	1.5	3.900	1.636	6	1	3.250	2.806	7.5	3	6.167
sea07sp3	0.935	9	4.5	6.600	1.517	8.5	3	6.167	1.992	8	6	8.333
sfo01sp1	0.764	4.5	3.5	4.000	0.707	4.5	2	3.667	2.466	6.5	4	5.667
sfo01sp2	0.764	6	4	4.667	1.155	6	3.5	5.250	2.475	7	4	5.000
sfo01sp4	0.577	7	6	6.667	0.764	7.5	6.5	7.333	0.764	8	7	7.000
sfo02sp1	1.652	7	4	5.125	0.854	6	5	6.125	1.436	8	3	5.500
sfo02sp3	0.479	3	2.5	4.750	1.555	6	2	4.625	1.797	6	3	4.500
sfo04sp1	1.708	8	4.5	5.250	1.061	6	1.5	3.375	1.931	5.5	4	6.000
sfo04sp2	1.683	6.5	4	6.000	1.803	7.5	3	6.125	2.097	7.5	3	4.250
sfo05sp1	0.742	4	5.5	6.625	0.854	7.5	2	5.700	2.280	8	2	2.600
sfo05sp2	0.500	2	5.5	6.700	1.151	8.5	5.5	6.900	1.517	9	1	2.000
sfo05sp3	2.080	6	5	6.375	1.377	8	3	5.400	1.917	7.5	3	5.400
sfo05sp4	1.387	4.5	4.5	5.625	1.109	7	3	4.400	1.475	6	3	3.400
sfo06sp1	0.908	8.5	4.5	6.375	1.315	7.5	4	6.800	1.605	8	8	8.000
sfo06sp2	0.000	8	5	6.875	1.315	8	4.5	6.250	1.443	8	7	8.000
sfo07sp1	0.837	8.5	4	5.375	1.601	7	3	5.100	2.012	7	7	7.800
smf02sp1	1.342	4	3	5.000	1.414	6	1	5.200	2.885	8.5	1	1.600
smf03sp1	0.418	9	5.5	6.500	1.414	7.5	3.5	6.700	1.956	8.5	9	9.000
smf03sp2	1.351	8.5	5.5	6.750	1.768	8	6.5	7.500	0.935	8.5	7	7.600
smf04sp1	1.871	7	5.5	6.125	0.629	7	4	5.900	1.517	8	3	6.000
smf04sp2	2.247	8	6.5	7.625	0.854	8.5	7.5	7.900	0.418	8.5	4	5.200
smf04sp3	0.418	9	6.5	7.250	0.645	8	7	7.600	0.548	8.5	8	8.400
smf05sp1	0.250	8	7	7.833	0.764	8.5	7	7.875	0.629	8.5	8	8.000
smf06sp1	0.250	9	2.5	5.667	2.843	8	3	6.500	2.345	8	7	8.250
smf06sp2	0.629	9	7.5	7.667	0.289	8	8	8.125	0.250	8.5	8	8.750
smf06sp3	0.500	8.5	7.5	7.667	0.289	8	7	7.750	0.645	8.5	8	8.500
smf07sp1	2.136	8.5	5.5	6.625	1.109	8	4	6.375	1.652	7.5	5	6.250
smf08sp1	1.440	7.5	5.5	6.667	1.258	8	3	6.100	2.104	8.5	5	6.600
smf08sp2	1.673	5	6.5	6.667	0.289	7	3	5.800	1.605	7	2	4.800
smf08sp3	2.535	7.5	5	6.167	1.258	7.5	4	6.300	1.605	8	2	5.600
smf09sp1	1.541	6.5	2	3.750	1.555	5.5	1.5	3.900	2.162	7	3	4.800
smf10sp1	2.750	7	3.5	4.500	1.323	6	2	3.400	1.140	5	3	4.000
smf10sp2	0.274	1.5	4	4.833	1.041	6	3	5.400	2.434	9	1	1.250
smf11sp1	0.753	8.5	6.5	7.200	0.837	8.5	6.5	7.500	0.837	9	6	7.600
smf11sp2	2.016	8	8	8.000	0.000	8	8	8.750	0.500	9	7	8.000

space	EGStdDev	EGMax	EHMin	EHMean	EHStdDev	EHMax	DAarea10	DAarea20	DAarea30	DAarea40	DAarea50	DAarea60
nyc01sp1	2.066	8	4	6.250	1.782	8	0.986	0.981	0.973	0.962	0.936	0.916
nyc01sp2	1.329	8	3.5	5.583	1.068	6.5	0.908	0.859	0.819	0.742	0.681	0.569
nyc02sp1	0.951	8	4	6.286	1.380	8.5	0.687	0.652	0.620	0.582	0.509	0.443
nyc02sp2	1.291	8	4	6.286	1.220	7.5	0.373	0.306	0.258	0.211	0.177	0.140
nyc04sp1	2.160	9	4	5.917	1.530	8.5	0.782	0.738	0.690	0.646	0.606	0.550
nyc04sp2	1.528	9	3	5.583	1.934	8.5	0.716	0.700	0.674	0.632	0.565	0.455
nyc05sp1	2.000	8	3.5	4.357	0.690	5.5	1.000	0.998	0.988	0.974	0.939	0.910
nyc05sp2	1.254	7	4	5.571	1.272	7	0.608	0.468	0.377	0.304	0.248	0.201
nyc08sp1	0.753	4	3	3.833	0.931	5	0.517	0.483	0.419	0.305	0.227	0.139
nyc08sp2	0.000	3	3	3.500	0.707	4	0.511	0.480	0.404	0.311	0.205	0.113
nyc09sp1	1.000	8	5.5	7.000	1.080	8	0.949	0.920	0.899	0.864	0.796	0.654
sea01sp1	1.414	8	5.5	6.750	1.369	9	0.696	0.630	0.571	0.500	0.434	0.311
sea01sp2	1.618	7	5	6.083	0.736	7	0.861	0.779	0.701	0.624	0.559	0.497
sea01sp3	1.000	8	5	6.800	1.304	8.5	1.000	1.000	0.986	0.965	0.891	0.708
sea02sp1	0.756	9	4	6.357	1.314	8	0.981	0.945	0.903	0.870	0.832	0.753
sea02sp2	0.816	4	3	4.071	1.134	6	0.537	0.482	0.398	0.314	0.250	0.196
sea02sp3	1.113	8	3	5.357	1.406	7.5	0.437	0.302	0.210	0.149	0.084	0.028
sea03sp1	1.732	8	3.5	5.429	1.397	7	0.991	0.907	0.684	0.543	0.412	0.282
sea03sp2	2.193	9	3.5	6.643	1.725	9	0.940	0.885	0.848	0.828	0.792	0.708
sea04sp1	1.033	9	4.5	6.500	1.342	8.5	0.924	0.880	0.811	0.739	0.635	0.490
sea04sp2	0.753	9	7.5	7.500	0.000	7.5	0.996	0.992	0.980	0.965	0.925	0.766
sea06sp1	1.472	6	4.5	6.500	1.225	7.5	0.722	0.668	0.599	0.487	0.451	0.422
sea06sp2	1.265	7	4.5	6.900	1.432	8	0.886	0.851	0.818	0.761	0.662	0.587
sea06sp3	0.894	9	5	6.500	1.140	8	1.000	0.993	0.984	0.977	0.918	0.721
sea06sp4	3.362	9	5.5	7.000	1.369	9	1.000	1.000	0.993	0.986	0.964	0.878
sea07sp1	1.211	6	3.5	6.200	1.605	7.5	0.703	0.650	0.601	0.554	0.505	0.454
sea07sp2	2.137	8	5	6.500	1.049	7.5	0.967	0.967	0.965	0.961	0.931	0.876
sea07sp3	1.211	9	6	7.300	1.204	9	1.000	0.999	0.997	0.986	0.949	0.859
sfo01sp1	1.528	7	5.5	6.500	1.323	8	0.918	0.886	0.865	0.834	0.817	0.777
sfo01sp2	1.000	6	5	6.333	1.258	7.5	0.962	0.953	0.926	0.859	0.779	0.712
sfo01sp4	0.000	7	6.5	7.000	0.500	7.5	0.968	0.960	0.952	0.931	0.897	0.845
sfo02sp1	1.915	7	4	5.875	1.436	7.5	0.991	0.991	0.991	0.991	0.991	0.990
sfo02sp3	1.732	7	3	4.125	1.109	5.5	0.836	0.791	0.745	0.664	0.545	0.452
sfo04sp1	1.414	7	5	6.000	1.155	7	1.000	1.000	1.000	0.997	0.939	0.560
sfo04sp2	0.957	5	5	6.500	1.323	7.5	0.471	0.437	0.413	0.388	0.363	0.338
sfo05sp1	0.894	4	2	4.800	2.197	8	0.627	0.612	0.568	0.524	0.490	0.467
sfo05sp2	1.000	3	2	2.833	1.041	4	0.137	0.097	0.043	0.001	0.000	0.000
sfo05sp3	1.517	7	3.5	5.500	1.826	7.5	0.639	0.358	0.148	0.017	0.009	0.000
sfo05sp4	0.548	4	3	4.000	0.913	5	0.679	0.662	0.616	0.534	0.494	0.444
sfo06sp1	0.000	8	5	7.000	1.173	8	1.000	1.000	0.999	0.960	0.877	0.722
sfo06sp2	0.816	9	6.5	7.625	0.854	8.5	1.000	1.000	1.000	1.000	1.000	1.000
sfo07sp1	0.447	8	4.5	6.600	1.294	8	1.000	1.000	1.000	0.995	0.980	0.940
smf02sp1	0.894	3	3	5.100	1.673	7	0.283	0.188	0.128	0.092	0.064	0.043
smf03sp1	0.000	9	5.5	7.800	1.525	9	1.000	1.000	1.000	1.000	1.000	1.000
smf03sp2	0.548	8	5	7.500	1.458	8.5	1.000	1.000	1.000	1.000	1.000	1.000
smf04sp1	1.871	8	5.5	7.250	1.190	8	0.893	0.856	0.819	0.760	0.707	0.624
smf04sp2	1.789	8	4	6.400	1.981	8	0.955	0.932	0.898	0.855	0.813	0.747
smf04sp3	0.548	9	5.5	6.875	1.377	8.5	1.000	1.000	0.999	0.998	0.991	0.989
smf05sp1	0.000	8	5	6.500	1.500	8	0.999	0.999	0.995	0.987	0.974	0.931
smf06sp1	0.957	9	5	6.250	0.957	7	0.945	0.945	0.943	0.935	0.930	0.928
smf06sp2	0.500	9	7.5	8.000	0.408	8.5	0.976	0.974	0.971	0.971	0.970	0.957
smf06sp3	0.577	9	7	7.250	0.289	7.5	0.949	0.923	0.893	0.848	0.811	0.758
smf07sp1	1.258	8	5	6.625	1.109	7.5	0.998	0.995	0.990	0.981	0.973	0.961
smf08sp1	1.140	8	6	6.900	0.894	8	1.000	0.998	0.956	0.856	0.806	0.737
smf08sp2	1.643	6	3.5	5.500	1.173	6.5	0.667	0.627	0.597	0.562	0.535	0.489
smf08sp3	2.510	8	4	6.200	1.605	8	0.987	0.978	0.968	0.957	0.931	0.887
smf09sp1	1.643	7	3.5	4.000	0.707	4.5	0.924	0.871	0.832	0.790	0.743	0.672
smf10sp1	0.816	5	2.5	3.800	1.095	5.5	0.171	0.133	0.117	0.091	0.070	0.054
smf10sp2	0.500	2	1	2.100	0.962	3.5	0.968	0.964	0.962	0.943	0.911	0.868
smf11sp1	1.140	9	7	7.375	0.250	7.5	1.000	1.000	1.000	0.999	0.998	0.997
smf11sp2	0.816	9	7.5	8.167	0.764	9	0.056	0.056	0.025	0.025	0.019	0.000

space	DAarea70	DAarea80	DAarea90	NBDAarea	NBDAarea	NBDAarea	NBDAarea	NBDAarea	NBDAarea	NBDAarea	NBDAarea	NBDAarea
nyc01sp1	0.860	0.719	0.460	0.986	0.981	0.973	0.962	0.936	0.916	0.860	0.719	0.460
nyc01sp2	0.444	0.236	0.000	0.941	0.907	0.871	0.824	0.763	0.690	0.556	0.339	0.000
nyc02sp1	0.376	0.303	0.156	0.743	0.710	0.683	0.660	0.629	0.594	0.515	0.423	0.253
nyc02sp2	0.115	0.074	0.036	0.414	0.334	0.288	0.245	0.195	0.160	0.126	0.084	0.037
nyc04sp1	0.494	0.431	0.260	0.832	0.796	0.770	0.739	0.707	0.664	0.601	0.531	0.345
nyc04sp2	0.388	0.306	0.169	0.814	0.779	0.763	0.733	0.706	0.671	0.621	0.539	0.354
nyc05sp1	0.871	0.801	0.602	1.000	1.000	0.999	0.993	0.988	0.974	0.909	0.820	0.617
nyc05sp2	0.135	0.066	0.006	0.824	0.651	0.515	0.412	0.328	0.271	0.222	0.153	0.054
nyc08sp1	0.095	0.057	0.031	0.611	0.536	0.505	0.463	0.402	0.285	0.205	0.121	0.055
nyc08sp2	0.085	0.055	0.029	0.593	0.524	0.498	0.464	0.393	0.302	0.191	0.102	0.051
nyc09sp1	0.490	0.287	0.000	0.949	0.920	0.899	0.864	0.796	0.654	0.490	0.287	0.000
sea01sp1	0.239	0.135	0.042	0.696	0.630	0.571	0.503	0.434	0.313	0.239	0.136	0.042
sea01sp2	0.452	0.375	0.141	0.941	0.897	0.834	0.757	0.646	0.535	0.456	0.378	0.142
sea01sp3	0.529	0.349	0.058	1.000	1.000	0.986	0.965	0.892	0.718	0.537	0.358	0.063
sea02sp1	0.622	0.419	0.107	0.997	0.990	0.981	0.954	0.914	0.861	0.755	0.476	0.109
sea02sp2	0.154	0.108	0.015	0.581	0.531	0.480	0.399	0.307	0.231	0.169	0.116	0.020
sea02sp3	0.018	0.011	0.001	0.541	0.323	0.217	0.154	0.086	0.028	0.020	0.013	0.003
sea03sp1	0.195	0.143	0.044	0.992	0.992	0.992	0.992	0.979	0.844	0.644	0.495	0.237
sea03sp2	0.458	0.000	0.000	0.940	0.885	0.848	0.828	0.792	0.708	0.458	0.000	0.000
sea04sp1	0.192	0.128	0.051	0.924	0.880	0.811	0.739	0.635	0.490	0.192	0.128	0.051
sea04sp2	0.267	0.054	0.005	0.998	0.994	0.985	0.975	0.958	0.895	0.620	0.121	0.005
sea06sp1	0.330	0.141	0.020	0.774	0.735	0.694	0.639	0.539	0.461	0.422	0.343	0.093
sea06sp2	0.448	0.299	0.084	0.890	0.856	0.829	0.793	0.715	0.642	0.526	0.360	0.115
sea06sp3	0.553	0.413	0.265	1.000	1.000	1.000	1.000	0.986	0.977	0.934	0.685	0.361
sea06sp4	0.468	0.000	0.000	1.000	1.000	0.993	0.986	0.964	0.878	0.468	0.000	0.000
sea07sp1	0.401	0.337	0.175	0.703	0.650	0.601	0.554	0.505	0.454	0.401	0.337	0.175
sea07sp2	0.743	0.000	0.000	0.967	0.967	0.967	0.965	0.963	0.950	0.877	0.586	0.000
sea07sp3	0.689	0.506	0.154	1.000	0.999	0.997	0.986	0.949	0.859	0.689	0.506	0.154
sfo01sp1	0.649	0.149	0.034	0.918	0.886	0.865	0.834	0.817	0.777	0.649	0.149	0.034
sfo01sp2	0.628	0.530	0.385	0.971	0.971	0.967	0.965	0.961	0.957	0.934	0.763	0.433
sfo01sp4	0.755	0.552	0.351	0.970	0.967	0.958	0.948	0.922	0.869	0.793	0.602	0.369
sfo02sp1	0.975	0.883	0.579	0.991	0.991	0.991	0.991	0.991	0.991	0.986	0.957	0.620
sfo02sp3	0.355	0.265	0.136	0.852	0.817	0.775	0.735	0.672	0.568	0.479	0.367	0.196
sfo04sp1	0.293	0.157	0.080	1.000	1.000	1.000	1.000	1.000	0.999	0.999	0.953	0.612
sfo04sp2	0.307	0.218	0.056	0.509	0.463	0.434	0.410	0.383	0.361	0.336	0.303	0.192
sfo05sp1	0.439	0.417	0.295	0.627	0.612	0.568	0.524	0.490	0.467	0.439	0.417	0.295
sfo05sp2	0.000	0.000	0.000	0.137	0.097	0.043	0.001	0.000	0.000	0.000	0.000	0.000
sfo05sp3	0.000	0.000	0.000	0.639	0.358	0.148	0.017	0.009	0.000	0.000	0.000	0.000
sfo05sp4	0.403	0.351	0.295	0.695	0.687	0.682	0.679	0.666	0.632	0.552	0.507	0.434
sfo06sp1	0.494	0.000	0.000	1.000	1.000	0.999	0.960	0.877	0.722	0.494	0.000	0.000
sfo06sp2	1.000	0.998	0.992	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.998	0.992
sfo07sp1	0.866	0.696	0.208	1.000	1.000	1.000	0.995	0.985	0.953	0.891	0.742	0.235
smf02sp1	0.035	0.024	0.007	0.283	0.188	0.128	0.092	0.064	0.043	0.035	0.024	0.007
smf03sp1	1.000	1.000	0.987	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.996
smf03sp2	1.000	1.000	0.977	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.988
smf04sp1	0.537	0.440	0.236	0.931	0.890	0.856	0.819	0.753	0.666	0.564	0.449	0.248
smf04sp2	0.676	0.600	0.393	0.955	0.932	0.898	0.855	0.813	0.747	0.676	0.600	0.393
smf04sp3	0.967	0.932	0.753	1.000	1.000	0.999	0.998	0.991	0.989	0.967	0.932	0.753
smf05sp1	0.791	0.478	0.000	0.999	0.999	0.995	0.987	0.974	0.931	0.791	0.478	0.000
smf06sp1	0.922	0.849	0.386	0.945	0.945	0.943	0.935	0.930	0.928	0.922	0.849	0.389
smf06sp2	0.936	0.884	0.384	0.976	0.974	0.973	0.971	0.971	0.963	0.950	0.907	0.653
smf06sp3	0.701	0.564	0.000	0.949	0.923	0.893	0.848	0.811	0.758	0.701	0.564	0.000
smf07sp1	0.940	0.852	0.197	0.998	0.995	0.990	0.981	0.973	0.961	0.940	0.852	0.197
smf08sp1	0.662	0.565	0.416	1.000	1.000	1.000	1.000	1.000	0.998	0.998	0.978	0.756
smf08sp2	0.444	0.379	0.237	0.735	0.671	0.638	0.612	0.580	0.550	0.511	0.439	0.283
smf08sp3	0.860	0.756	0.435	0.987	0.979	0.970	0.962	0.938	0.904	0.868	0.799	0.496
smf09sp1	0.577	0.446	0.210	0.924	0.871	0.832	0.790	0.743	0.672	0.577	0.446	0.210
smf10sp1	0.036	0.008	0.000	0.178	0.144	0.121	0.096	0.079	0.059	0.039	0.015	0.000
smf10sp2	0.650	0.285	0.034	0.968	0.964	0.962	0.943	0.911	0.872	0.665	0.292	0.034
smf11sp1	0.983	0.904	0.435	1.000	1.000	1.000	0.999	0.998	0.997	0.983	0.904	0.435
smf11sp2	0.000	0.000	0.000	0.056	0.056	0.025	0.025	0.019	0.000	0.000	0.000	0.000

space	BCDAarea1	BCDAarea2	BCDAarea3	BCDAarea4	BCDAarea5	BCDAarea6	BCDAarea7	BCDAarea8	BCDAarea9	WorkMax0	WorkMaxI	WorkMaxI
nyc01sp1	0.986	0.981	0.973	0.962	0.936	0.916	0.860	0.719	0.460	1.090	2673.000	6345.000
nyc01sp2	0.066	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.868	1515.000	4264.500
nyc02sp1	0.357	0.248	0.195	0.150	0.115	0.074	0.042	0.006	0.000	2.923	1953.000	4926.000
nyc02sp2	0.069	0.043	0.028	0.015	0.010	0.005	0.000	0.000	0.000	4.109	425.500	1871.700
nyc04sp1	0.602	0.547	0.515	0.466	0.434	0.408	0.375	0.315	0.175	3.263	3117.000	########
nyc04sp2	0.309	0.240	0.048	0.021	0.000	0.000	0.000	0.000	0.000	2.109	5153.000	########
nyc05sp1	0.282	0.175	0.065	0.003	0.000	0.000	0.000	0.000	0.000	1.698	1809.000	6504.800
nyc05sp2	0.073	0.021	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.311	1864.000	4948.400
nyc08sp1	0.059	0.037	0.022	0.004	0.000	0.000	0.000	0.000	0.000	2.832	1375.500	3429.400
nyc08sp2	0.064	0.035	0.022	0.000	0.000	0.000	0.000	0.000	0.000	2.805	1410.000	3319.700
nyc09sp1	0.949	0.920	0.899	0.864	0.796	0.654	0.490	0.287	0.000	1.066	7748.500	9034.400
sea01sp1	0.120	0.086	0.069	0.057	0.046	0.025	0.000	0.000	0.000	2.042	938.500	2414.800
sea01sp2	0.419	0.369	0.313	0.253	0.200	0.148	0.085	0.002	0.000	2.684	3791.000	8998.500
sea01sp3	0.246	0.181	0.123	0.084	0.052	0.008	0.000	0.000	0.000	1.478	1336.000	2587.600
sea02sp1	0.836	0.713	0.579	0.477	0.374	0.262	0.142	0.026	0.000	2.691	2644.500	8343.000
sea02sp2	0.151	0.122	0.100	0.072	0.046	0.025	0.001	0.000	0.000	6.103	1695.500	2648.600
sea02sp3	0.283	0.208	0.154	0.099	0.046	0.001	0.000	0.000	0.000	5.586	501.000	1357.800
sea03sp1	0.262	0.178	0.131	0.050	0.000	0.000	0.000	0.000	0.000	1.980	5187.500	########
sea03sp2	0.940	0.885	0.848	0.828	0.792	0.708	0.458	0.000	0.000	2.271	6492.000	########
sea04sp1	0.924	0.880	0.811	0.739	0.635	0.490	0.192	0.128	0.051	3.825	4005.000	########
sea04sp2	0.515	0.406	0.301	0.133	0.019	0.014	0.009	0.004	0.000	4.056	1907.500	8119.100
sea06sp1	0.170	0.121	0.103	0.094	0.080	0.059	0.021	0.000	0.000	4.479	3147.000	7219.800
sea06sp2	0.360	0.353	0.345	0.331	0.309	0.263	0.203	0.138	0.023	2.117	3258.000	7203.100
sea06sp3	0.445	0.311	0.217	0.153	0.128	0.096	0.068	0.046	0.016	5.339	6976.000	########
sea06sp4	1.000	1.000	0.993	0.986	0.964	0.878	0.468	0.000	0.000	0.336	564.500	1123.600
sea07sp1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.199	2268.000	4994.400
sea07sp2	0.692	0.214	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.719	1253.500	2937.400
sea07sp3	0.205	0.180	0.156	0.138	0.120	0.109	0.098	0.074	0.000	1.927	2319.000	5440.200
sfo01sp1	0.918	0.886	0.865	0.834	0.817	0.777	0.649	0.149	0.034	0.963	1132.000	2987.000
sfo01sp2	0.427	0.367	0.334	0.310	0.290	0.272	0.224	0.160	0.018	4.966	1922.000	6770.000
sfo01sp4	0.860	0.798	0.722	0.621	0.496	0.371	0.226	0.075	0.000	2.049	1894.000	4306.400
sfo02sp1	0.994	0.994	0.994	0.993	0.988	0.978	0.892	0.698	0.394	1.422	3743.000	5823.800
sfo02sp3	0.233	0.156	0.100	0.059	0.034	0.007	0.000	0.000	0.000	2.526	783.000	3499.400
sfo04sp1	0.237	0.124	0.069	0.000	0.000	0.000	0.000	0.000	0.000	1.801	3066.000	8283.100
sfo04sp2	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.397	1043.000	2651.000
sfo05sp1	0.277	0.239	0.204	0.180	0.151	0.120	0.074	0.025	0.000	1.409	1859.000	2897.400
sfo05sp2	0.137	0.097	0.043	0.001	0.000	0.000	0.000	0.000	0.000	3.442	136.000	781.100
sfo05sp3	0.639	0.358	0.148	0.017	0.009	0.000	0.000	0.000	0.000	0.952	2423.000	4580.800
sfo05sp4	0.426	0.368	0.328	0.295	0.262	0.234	0.179	0.120	0.014	2.731	3341.000	5494.100
sfo06sp1	1.000	1.000	0.999	0.960	0.877	0.722	0.494	0.000	0.000	0.257	704.000	1105.000
sfo06sp2	1.000	1.000	0.999	0.998	0.997	0.992	0.983	0.965	0.839	1.258	8237.000	########
sfo07sp1	0.995	0.983	0.966	0.928	0.858	0.763	0.648	0.400	0.030	3.355	3247.000	8489.800
smf02sp1	0.283	0.188	0.128	0.092	0.064	0.043	0.035	0.024	0.007	3.553	287.000	2299.800
smf03sp1	0.434	0.048	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.025	1996.000	6116.000
smf03sp2	0.408	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.966	2677.000	6624.000
smf04sp1	0.577	0.476	0.440	0.411	0.381	0.313	0.181	0.099	0.000	4.297	1673.000	5023.400
smf04sp2	0.313	0.266	0.229	0.181	0.143	0.096	0.053	0.028	0.000	0.938	2477.500	3805.500
smf04sp3	0.998	0.995	0.988	0.981	0.955	0.916	0.817	0.672	0.264	0.695	3140.500	5064.000
smf05sp1	0.999	0.999	0.995	0.987	0.974	0.931	0.791	0.478	0.000	0.290	811.000	1315.300
smf06sp1	0.913	0.903	0.856	0.812	0.728	0.558	0.334	0.109	0.000	0.712	1703.000	3349.200
smf06sp2	0.849	0.805	0.749	0.707	0.638	0.575	0.485	0.357	0.002	0.837	2143.000	4116.400
smf06sp3	0.726	0.665	0.606	0.533	0.470	0.382	0.316	0.182	0.000	0.573	1676.000	3006.000
smf07sp1	0.998	0.995	0.990	0.981	0.973	0.961	0.940	0.852	0.197	1.288	1652.500	3825.600
smf08sp1	0.851	0.790	0.720	0.651	0.587	0.488	0.402	0.263	0.100	4.897	3130.500	6658.400
smf08sp2	0.547	0.464	0.410	0.363	0.320	0.269	0.221	0.142	0.022	25.790	1436.500	4237.200
smf08sp3	0.443	0.381	0.337	0.279	0.226	0.190	0.144	0.054	0.000	1.697	1468.500	4066.800
smf09sp1	0.924	0.871	0.832	0.790	0.743	0.672	0.577	0.446	0.210	3.581	3933.000	########
smf10sp1	0.066	0.061	0.054	0.043	0.037	0.027	0.016	0.006	0.000	3.605	143.000	864.000
smf10sp2	0.966	0.964	0.958	0.927	0.886	0.836	0.558	0.201	0.031	2.536	478.500	1142.600
smf11sp1	0.994	0.993	0.985	0.967	0.929	0.872	0.766	0.494	0.027	0.795	1548.000	3203.300
smf11sp2	0.025	0.025	0.025	0.006	0.000	0.000	0.000	0.000	0.000	0.754	57.000	173.500

space	WorkMaxI	WorkMaxt	Work90CV	Work90IQ	hMaxCV	hMaxIQR	hMaxIDR	hMaxMM	hMaxtenN	h90CV	h90IQR	h90IDR
nyc01sp1	0.090	0.349	0.698	1408.000	0.684	1875.000	2945.000	0.221	0.500	0.538	1010.100	1540.500
nyc01sp2	0.151	0.501	0.773	424.000	1.308	797.500	1649.000	0.136	0.344	1.003	365.550	1117.850
nyc02sp1	0.038	0.139	1.607	1068.000	1.268	693.000	1310.100	0.006	0.203	0.977	430.500	824.150
nyc02sp2	0.038	0.238	2.241	261.500	0.734	215.500	406.400	0.122	0.333	0.514	119.500	205.020
nyc04sp1	0.031	0.176	2.167	1905.000	1.466	1732.500	3814.300	0.065	0.251	1.138	927.650	1887.470
nyc04sp2	0.015	0.077	1.366	2105.100	1.390	1465.000	3433.400	0.033	0.127	1.273	735.500	1869.990
nyc05sp1	0.167	0.390	0.808	1152.000	0.738	811.000	1931.500	0.253	0.525	0.402	519.000	903.000
nyc05sp2	0.032	0.482	1.264	410.000	1.037	430.000	1067.200	0.273	0.519	0.750	208.100	387.040
nyc08sp1	0.013	0.077	2.242	707.500	2.177	1052.500	4169.800	0.017	0.083	1.983	553.550	2255.290
nyc08sp2	0.015	0.116	2.236	677.000	1.905	1464.500	4585.500	0.026	0.111	1.745	716.550	2311.100
nyc09sp1	0.005	0.369	0.817	1925.200	0.805	2428.000	4216.800	0.250	0.411	0.713	1103.000	2192.810
sea01sp1	0.020	0.131	1.208	689.500	0.953	1088.500	2140.100	0.001	0.331	0.778	761.100	1387.960
sea01sp2	0.001	0.165	1.811	1686.000	1.525	1583.000	3105.000	0.057	0.333	1.136	951.100	1929.000
sea01sp3	0.244	0.479	0.769	828.000	0.943	851.000	1809.500	0.246	0.473	0.605	574.000	1208.550
sea02sp1	0.013	0.236	1.395	1199.600	1.588	1340.000	4485.100	0.000	0.058	1.078	697.100	1915.310
sea02sp2	0.031	0.147	2.447	515.550	2.008	362.000	1314.000	0.048	0.333	1.723	217.000	809.290
sea02sp3	0.016	0.155	2.386	320.600	3.207	163.000	356.400	0.024	0.305	1.892	66.550	172.410
sea03sp1	0.000	0.169	1.513	1844.500	1.150	1580.000	3654.800	0.131	0.295	1.084	693.000	1610.790
sea03sp2	0.012	0.400	0.829	1045.100	10.065	780.000	1456.000	0.143	1.000	0.722	210.050	386.090
sea04sp1	0.051	0.308	1.624	991.300	0.988	1286.000	2832.800	0.083	0.304	0.817	941.100	2182.240
sea04sp2	0.055	0.492	1.978	396.000	1.284	901.500	2026.100	0.135	0.544	0.738	509.000	1406.200
sea06sp1	0.002	0.095	1.897	1255.100	1.373	1752.000	3938.400	0.001	0.152	1.173	901.500	1897.000
sea06sp2	0.014	0.143	1.373	2242.000	1.725	1550.500	3898.600	0.003	0.071	1.676	1105.050	2561.070
sea06sp3	0.091	0.298	2.737	2313.300	1.607	2525.000	4502.500	0.125	0.421	1.014	1297.000	2238.800
sea06sp4	0.397	0.674	0.275	271.100	0.345	460.000	791.200	0.536	0.687	0.296	223.000	387.600
sea07sp1	0.006	0.105	1.165	1431.050	0.873	1172.000	1858.100	0.114	0.265	0.820	824.000	1325.130
sea07sp2	0.050	0.725	0.344	315.050	0.450	1319.000	1829.100	0.381	0.625	0.386	813.000	1265.460
sea07sp3	0.126	0.326	0.801	1375.200	0.541	1052.000	1710.900	0.225	0.422	0.490	709.100	1156.890
sfo01sp1	0.024	0.174	0.725	923.100	1.468	295.000	756.900	0.087	0.355	1.182	184.000	527.710
sfo01sp2	0.002	0.223	2.082	1332.000	1.252	1372.000	3752.400	0.171	0.380	1.074	1133.100	2995.630
sfo01sp4	0.003	0.277	1.079	1254.100	1.044	1181.000	3176.500	0.070	0.237	0.962	640.000	1986.930
sfo02sp1	0.001	0.314	0.808	2838.200	1.077	1006.500	2245.500	0.125	0.363	0.808	782.050	1855.150
sfo02sp3	0.047	0.261	1.753	575.050	1.430	697.000	2036.000	0.074	0.274	1.229	499.000	1334.000
sfo04sp1	0.207	0.355	1.392	1452.000	0.870	2199.000	3864.700	0.167	0.528	0.771	1443.000	2354.600
sfo04sp2	0.000	0.100	1.689	613.100	1.643	1013.000	1943.400	0.023	0.098	1.130	609.000	1087.820
sfo05sp1	0.003	0.031	1.328	1519.100	1.347	1426.000	2492.200	0.013	0.055	1.262	1183.000	2075.880
sfo05sp2	0.006	0.053	1.706	82.000	1.410	186.000	435.200	0.025	0.100	1.275	110.000	269.190
sfo05sp3	0.318	0.580	0.479	317.100	0.755	1423.500	2355.000	0.420	0.616	0.539	245.050	452.420
sfo05sp4	0.008	0.037	2.072	1640.000	1.225	1770.000	3374.200	0.014	0.050	1.109	1375.000	2616.230
sfo06sp1	0.231	0.500	0.256	530.000	0.324	145.000	331.000	0.222	0.500	0.316	109.000	249.050
sfo06sp2	0.076	0.603	0.804	2973.100	1.139	2357.000	6102.300	0.001	0.760	0.504	1079.100	3633.710
sfo07sp1	0.106	0.523	2.136	628.150	0.788	1084.000	2108.900	0.294	0.558	0.628	856.500	1716.790
smf02sp1	0.082	0.306	2.701	204.000	1.119	492.000	1044.000	0.052	0.279	0.962	289.000	645.340
smf03sp1	0.235	0.619	0.499	1196.050	1.398	1180.500	3954.600	0.063	0.316	1.052	934.050	3155.210
smf03sp2	0.269	0.708	0.474	1172.000	1.449	1330.000	2672.900	0.148	0.543	0.843	829.000	2253.900
smf04sp1	0.046	0.240	1.974	806.050	2.358	1169.000	4823.500	0.049	0.241	1.941	750.000	2436.400
smf04sp2	0.065	0.210	0.858	1303.050	0.809	1359.000	2586.500	0.118	0.246	0.728	1182.050	2242.700
smf04sp3	0.069	0.265	0.662	2059.550	0.740	2093.500	4018.000	0.130	0.244	0.715	1545.000	2919.600
smf05sp1	0.074	0.479	0.287	663.000	0.275	77.000	145.000	0.429	0.750	0.156	62.000	118.000
smf06sp1	0.002	0.410	0.490	833.000	0.893	1043.000	2810.900	0.134	0.392	0.829	946.000	2418.410
smf06sp2	0.005	0.483	0.423	1173.050	0.835	950.000	2443.000	0.182	0.504	0.663	783.000	2052.960
smf06sp3	0.007	0.248	0.546	1279.000	0.985	439.000	1554.000	0.026	0.273	0.840	379.000	1315.820
smf07sp1	0.097	0.493	0.516	466.000	0.782	594.000	1404.500	0.136	0.402	0.765	448.500	1077.600
smf08sp1	0.128	0.284	2.209	1331.200	16.152	2038.000	4519.800	0.026	0.262	3.579	1089.000	2695.660
smf08sp2	0.011	5.208	4.283	753.050	16.216	458.000	1464.500	0.006	0.160	4.970	312.500	1081.310
smf08sp3	5.383	2.339	0.779	629.000	2.231	1052.000	2369.800	0.022	0.202	1.071	749.100	1665.420
smf09sp1	0.015	0.361	2.744	892.550	2.011	1283.000	2661.000	0.036	0.222	1.515	717.200	1863.050
smf10sp1	0.002	0.173	2.730	126.000	1.981	110.500	310.500	0.024	0.250	1.360	87.000	263.500
smf10sp2	0.002	0.408	1.465	396.550	1.403	141.000	441.000	0.060	0.491	0.968	108.000	334.500
smf11sp1	0.126	0.442	0.637	1173.100	0.656	814.000	1631.500	0.186	0.337	0.637	721.100	1443.050
smf11sp2	0.296	0.533	0.663	47.500	0.591	62.000	133.100	0.273	0.500	0.492	52.500	113.100

space	h90MM	h90tenNin	hMedCV	hMedIQR	hMedIDR	hMedMM	hMedtenN	q200	q300	q2000	q3000	q5000
nyc01sp1	0.194	0.381	0.486	495.000	773.500	0.138	0.255	0.116	0.177	0.892	0.975	0.999
nyc01sp2	0.088	0.216	0.855	187.000	535.200	0.073	0.169	0.258	0.425	0.994	0.998	1.000
nyc02sp1	0.001	0.122	0.701	165.000	327.150	0.000	0.103	0.429	0.532	0.939	0.972	0.993
nyc02sp2	0.099	0.304	0.450	61.000	104.400	0.087	0.287	0.677	0.805	0.985	0.992	0.997
nyc04sp1	0.035	0.105	0.845	474.250	956.400	0.028	0.081	0.327	0.438	0.863	0.918	0.956
nyc04sp2	0.018	0.081	0.879	412.000	877.650	0.012	0.058	0.426	0.503	0.895	0.951	0.989
nyc05sp1	0.203	0.459	0.312	253.000	435.750	0.165	0.423	0.095	0.154	0.917	0.975	0.993
nyc05sp2	0.233	0.461	0.332	90.000	158.200	0.202	0.412	0.562	0.713	0.984	0.993	0.997
nyc08sp1	0.010	0.050	1.691	149.000	498.150	0.007	0.037	0.658	0.742	0.969	0.984	0.992
nyc08sp2	0.013	0.063	1.466	178.500	477.150	0.009	0.049	0.675	0.752	0.972	0.985	0.993
nyc09sp1	0.169	0.331	0.489	342.000	603.950	0.144	0.266	0.253	0.371	0.951	0.968	0.986
sea01sp1	0.000	0.230	0.719	303.500	548.050	0.000	0.176	0.481	0.607	0.972	0.990	0.999
sea01sp2	0.024	0.127	0.864	507.000	914.500	0.018	0.107	0.325	0.455	0.880	0.935	0.975
sea01sp3	0.184	0.366	0.566	269.000	551.000	0.137	0.293	0.206	0.301	0.962	0.993	1.000
sea02sp1	0.000	0.026	1.008	300.000	858.050	0.000	0.011	0.206	0.310	0.900	0.948	0.980
sea02sp2	0.024	0.158	1.431	79.000	233.900	0.018	0.111	0.606	0.717	0.966	0.984	0.994
sea02sp3	0.007	0.202	1.475	20.500	60.000	0.005	0.158	0.742	0.836	0.994	0.997	0.998
sea03sp1	0.074	0.164	0.900	112.000	264.300	0.058	0.125	0.445	0.531	0.915	0.956	0.987
sea03sp2	0.095	0.544	0.262	27.000	60.000	0.074	0.508	0.299	0.405	0.935	0.966	0.985
sea04sp1	0.057	0.206	0.719	400.000	860.150	0.050	0.183	0.315	0.466	0.940	0.969	0.988
sea04sp2	0.087	0.444	0.486	134.000	329.050	0.070	0.351	0.239	0.355	0.975	0.989	0.995
sea06sp1	0.000	0.083	1.095	334.750	665.900	0.000	0.070	0.474	0.576	0.941	0.976	0.994
sea06sp2	0.001	0.045	1.606	476.750	1168.350	0.001	0.039	0.315	0.417	0.874	0.928	0.970
sea06sp3	0.079	0.289	0.554	445.500	865.800	0.067	0.260	0.200	0.273	0.841	0.909	0.964
sea06sp4	0.468	0.603	0.240	84.000	151.600	0.410	0.540	0.219	0.323	1.000	1.000	1.000
sea07sp1	0.064	0.175	0.761	327.000	554.350	0.042	0.121	0.424	0.528	0.929	0.976	0.998
sea07sp2	0.296	0.525	0.266	242.000	426.550	0.227	0.407	0.205	0.302	0.969	0.997	1.000
sea07sp3	0.184	0.333	0.478	372.000	604.750	0.167	0.286	0.157	0.236	0.900	0.957	0.994
sfo01sp1	0.075	0.338	0.869	71.000	184.350	0.040	0.265	0.253	0.354	0.927	0.991	0.998
sfo01sp2	0.077	0.216	0.882	457.000	1088.200	0.046	0.154	0.150	0.282	0.872	0.934	0.977
sfo01sp4	0.053	0.205	0.779	325.000	857.950	0.042	0.166	0.144	0.231	0.899	0.969	0.994
sfo02sp1	0.084	0.297	0.638	339.750	705.000	0.055	0.237	0.074	0.117	0.693	0.825	0.946
sfo02sp3	0.033	0.196	0.902	240.000	585.000	0.017	0.130	0.320	0.477	0.966	0.985	0.994
sfo04sp1	0.093	0.249	0.607	603.500	956.700	0.073	0.192	0.297	0.348	0.926	0.971	0.990
sfo04sp2	0.020	0.090	1.064	410.000	717.500	0.017	0.084	0.581	0.676	0.989	0.996	0.998
sfo05sp1	0.010	0.042	1.145	821.000	1601.100	0.006	0.029	0.459	0.525	0.924	0.986	1.000
sfo05sp2	0.016	0.057	1.099	35.000	76.000	0.011	0.046	0.937	0.964	1.000	1.000	1.000
sfo05sp3	0.346	0.540	0.347	49.000	88.000	0.248	0.423	0.681	0.830	0.996	0.998	1.000
sfo05sp4	0.010	0.039	1.059	588.500	1103.500	0.008	0.034	0.446	0.517	0.898	0.951	0.983
sfo06sp1	0.196	0.475	0.316	41.000	94.000	0.194	0.472	0.245	0.351	0.998	1.000	1.000
sfo06sp2	0.000	0.707	0.305	516.000	1615.200	0.000	0.631	0.029	0.036	0.338	0.601	0.901
sfo07sp1	0.206	0.392	0.444	380.500	746.450	0.116	0.323	0.104	0.181	0.945	0.964	0.979
smf02sp1	0.031	0.251	0.632	87.000	176.400	0.018	0.196	0.819	0.890	0.982	0.988	0.994
smf03sp1	0.042	0.192	0.914	722.000	2428.250	0.039	0.157	0.032	0.039	0.525	0.815	0.980
smf03sp2	0.070	0.474	0.607	440.000	1243.150	0.052	0.280	0.038	0.053	0.680	0.904	0.990
smf04sp1	0.036	0.217	1.422	485.000	1159.000	0.019	0.172	0.182	0.367	0.956	0.980	0.992
smf04sp2	0.107	0.170	0.709	680.750	1319.750	0.097	0.149	0.163	0.267	0.934	0.990	1.000
smf04sp3	0.117	0.216	0.675	1159.250	2195.750	0.089	0.166	0.059	0.088	0.682	0.855	0.987
smf05sp1	0.391	0.687	0.154	30.000	56.000	0.376	0.674	0.160	0.242	0.982	1.000	1.000
smf06sp1	0.095	0.180	0.778	539.500	1265.800	0.076	0.149	0.136	0.179	0.855	0.974	1.000
smf06sp2	0.070	0.325	0.613	413.000	1083.700	0.056	0.265	0.113	0.151	0.790	0.951	0.999
smf06sp3	0.012	0.186	0.745	210.000	675.600	0.010	0.165	0.208	0.305	0.934	0.988	1.000
smf07sp1	0.089	0.286	0.715	323.500	802.500	0.081	0.234	0.089	0.153	0.988	0.997	1.000
smf08sp1	0.022	0.193	2.189	543.000	1860.900	0.006	0.081	0.119	0.252	0.892	0.941	0.977
smf08sp2	0.005	0.103	2.171	196.000	613.400	0.002	0.076	0.369	0.508	0.948	0.969	0.984
smf08sp3	0.019	0.194	1.033	492.500	1110.000	0.017	0.185	0.093	0.179	0.954	0.988	0.999
smf09sp1	0.023	0.150	1.266	242.000	1039.050	0.010	0.106	0.187	0.346	0.907	0.932	0.954
smf10sp1	0.018	0.143	1.192	54.000	161.500	0.011	0.103	0.852	0.918	0.993	0.995	0.998
smf10sp2	0.050	0.418	0.794	86.000	250.500	0.032	0.278	0.196	0.294	0.990	0.993	0.997
smf11sp1	0.172	0.309	0.567	451.000	879.000	0.151	0.247	0.079	0.120	0.769	0.938	0.998
smf11sp2	0.203	0.352	0.476	35.000	75.200	0.197	0.344	0.947	0.979	1.000	1.000	1.000

space	q400	q500	q750	q1000	q1500	qNB200	qNB300	qNB400	qNB500	qNB750	qNB1000	qNB1500
nyc01sp1	0.245	0.317	0.494	0.635	0.798	0.116	0.177	0.245	0.317	0.494	0.635	0.798
nyc01sp2	0.583	0.712	0.895	0.957	0.988	0.219	0.362	0.508	0.635	0.836	0.918	0.963
nyc02sp1	0.605	0.664	0.767	0.830	0.902	0.337	0.438	0.513	0.574	0.688	0.761	0.847
nyc02sp2	0.861	0.893	0.935	0.956	0.976	0.639	0.778	0.843	0.880	0.926	0.949	0.970
nyc04sp1	0.507	0.560	0.658	0.726	0.812	0.251	0.356	0.426	0.481	0.581	0.651	0.742
nyc04sp2	0.562	0.614	0.711	0.774	0.849	0.278	0.359	0.418	0.466	0.560	0.627	0.712
nyc05sp1	0.224	0.302	0.474	0.621	0.817	0.089	0.131	0.184	0.244	0.381	0.506	0.713
nyc05sp2	0.794	0.842	0.906	0.939	0.970	0.442	0.609	0.711	0.773	0.854	0.895	0.936
nyc08sp1	0.794	0.830	0.886	0.919	0.953	0.551	0.645	0.706	0.750	0.820	0.862	0.909
nyc08sp2	0.802	0.836	0.894	0.926	0.959	0.559	0.649	0.709	0.751	0.823	0.866	0.914
nyc09sp1	0.489	0.591	0.743	0.839	0.923	0.253	0.371	0.489	0.591	0.743	0.839	0.923
sea01sp1	0.692	0.753	0.848	0.900	0.951	0.481	0.606	0.691	0.752	0.848	0.899	0.951
sea01sp2	0.543	0.603	0.691	0.748	0.829	0.281	0.394	0.482	0.548	0.651	0.712	0.790
sea01sp3	0.394	0.483	0.665	0.788	0.910	0.204	0.298	0.391	0.480	0.663	0.786	0.910
sea02sp1	0.401	0.479	0.625	0.725	0.843	0.178	0.249	0.319	0.384	0.519	0.619	0.751
sea02sp2	0.780	0.823	0.883	0.914	0.948	0.558	0.674	0.742	0.790	0.856	0.891	0.928
sea02sp3	0.888	0.916	0.954	0.973	0.989	0.717	0.822	0.880	0.912	0.951	0.971	0.987
sea03sp1	0.604	0.661	0.753	0.808	0.875	0.171	0.237	0.302	0.363	0.501	0.590	0.691
sea03sp2	0.500	0.578	0.716	0.802	0.893	0.299	0.405	0.500	0.578	0.716	0.802	0.893
sea04sp1	0.593	0.688	0.813	0.867	0.915	0.315	0.466	0.593	0.688	0.813	0.867	0.915
sea04sp2	0.453	0.546	0.763	0.891	0.954	0.206	0.298	0.389	0.482	0.716	0.856	0.928
sea06sp1	0.645	0.698	0.783	0.838	0.905	0.378	0.488	0.562	0.620	0.717	0.779	0.855
sea06sp2	0.498	0.564	0.676	0.747	0.827	0.279	0.383	0.467	0.536	0.654	0.728	0.812
sea06sp3	0.342	0.407	0.553	0.659	0.777	0.115	0.162	0.214	0.267	0.397	0.508	0.644
sea06sp4	0.428	0.540	0.816	0.941	0.991	0.219	0.323	0.428	0.540	0.816	0.941	0.991
sea07sp1	0.600	0.651	0.737	0.797	0.879	0.424	0.528	0.600	0.651	0.737	0.797	0.879
sea07sp2	0.415	0.510	0.682	0.794	0.920	0.180	0.243	0.309	0.376	0.537	0.654	0.795
sea07sp3	0.321	0.408	0.591	0.709	0.833	0.157	0.236	0.321	0.408	0.591	0.709	0.833
sfo01sp1	0.437	0.504	0.629	0.717	0.840	0.253	0.354	0.437	0.504	0.629	0.717	0.840
sfo01sp2	0.407	0.510	0.657	0.731	0.818	0.114	0.159	0.223	0.311	0.504	0.613	0.723
sfo01sp4	0.323	0.408	0.571	0.680	0.820	0.135	0.212	0.297	0.377	0.541	0.656	0.800
sfo02sp1	0.163	0.211	0.326	0.420	0.577	0.069	0.102	0.139	0.181	0.289	0.387	0.548
sfo02sp3	0.604	0.695	0.818	0.880	0.940	0.254	0.410	0.545	0.646	0.782	0.852	0.917
sfo04sp1	0.414	0.502	0.661	0.756	0.870	0.063	0.095	0.152	0.243	0.437	0.559	0.710
sfo04sp2	0.740	0.788	0.876	0.930	0.975	0.532	0.633	0.702	0.753	0.848	0.906	0.958
sfo05sp1	0.578	0.621	0.697	0.758	0.856	0.459	0.525	0.578	0.621	0.697	0.758	0.856
sfo05sp2	0.978	0.987	0.996	0.997	0.999	0.937	0.964	0.978	0.987	0.996	0.997	0.999
sfo05sp3	0.893	0.927	0.964	0.979	0.992	0.681	0.830	0.893	0.927	0.964	0.979	0.992
sfo05sp4	0.585	0.634	0.709	0.766	0.847	0.356	0.410	0.467	0.516	0.598	0.657	0.752
sfo06sp1	0.454	0.540	0.703	0.810	0.946	0.245	0.351	0.454	0.540	0.703	0.810	0.946
sfo06sp2	0.044	0.054	0.088	0.132	0.226	0.029	0.036	0.044	0.054	0.088	0.131	0.225
sfo07sp1	0.277	0.386	0.638	0.805	0.920	0.101	0.170	0.260	0.365	0.620	0.792	0.912
smf02sp1	0.922	0.940	0.960	0.969	0.978	0.819	0.890	0.922	0.940	0.960	0.969	0.978
smf03sp1	0.048	0.061	0.100	0.152	0.320	0.031	0.038	0.046	0.055	0.082	0.112	0.186
smf03sp2	0.069	0.085	0.134	0.224	0.470	0.038	0.051	0.063	0.075	0.106	0.147	0.252
smf04sp1	0.528	0.625	0.755	0.836	0.921	0.164	0.333	0.490	0.594	0.731	0.812	0.901
smf04sp2	0.372	0.462	0.615	0.719	0.850	0.163	0.267	0.372	0.462	0.615	0.719	0.850
smf04sp3	0.122	0.157	0.254	0.356	0.541	0.059	0.088	0.122	0.157	0.254	0.356	0.541
smf05sp1	0.322	0.400	0.566	0.707	0.887	0.160	0.242	0.322	0.400	0.566	0.707	0.887
smf06sp1	0.227	0.285	0.437	0.564	0.740	0.136	0.179	0.227	0.284	0.437	0.563	0.740
smf06sp2	0.191	0.232	0.346	0.450	0.636	0.102	0.133	0.169	0.207	0.315	0.421	0.616
smf06sp3	0.388	0.464	0.619	0.724	0.867	0.208	0.305	0.388	0.464	0.619	0.724	0.867
smf07sp1	0.234	0.319	0.552	0.766	0.952	0.089	0.153	0.234	0.319	0.552	0.766	0.952
smf08sp1	0.372	0.466	0.630	0.731	0.839	0.056	0.083	0.120	0.168	0.312	0.449	0.634
smf08sp2	0.602	0.676	0.800	0.864	0.923	0.307	0.457	0.553	0.626	0.755	0.825	0.894
smf08sp3	0.293	0.415	0.654	0.783	0.905	0.085	0.163	0.275	0.396	0.639	0.771	0.897
smf09sp1	0.494	0.607	0.761	0.827	0.882	0.187	0.346	0.494	0.607	0.761	0.827	0.882
smf10sp1	0.953	0.969	0.985	0.989	0.991	0.842	0.912	0.947	0.964	0.981	0.985	0.988
smf10sp2	0.391	0.486	0.687	0.841	0.969	0.195	0.291	0.386	0.482	0.685	0.840	0.968
smf11sp1	0.166	0.214	0.335	0.444	0.627	0.079	0.120	0.166	0.214	0.335	0.444	0.627
smf11sp2	0.990	0.995	1.000	1.000	1.000	0.947	0.979	0.990	0.995	1.000	1.000	1.000

space	qNB2000	qNB3000	qNB5000	qBC200	qBC300	qBC400	qBC500	qBC750	qBC1000	qBC1500	qBC2000	qBC3000
nyc01sp1	0.892	0.975	0.999	0.116	0.177	0.245	0.317	0.494	0.635	0.798	0.892	0.975
nyc01sp2	0.974	0.983	0.991	0.920	0.963	0.974	0.979	0.987	0.991	0.996	0.998	1.000
nyc02sp1	0.891	0.931	0.958	0.764	0.848	0.892	0.916	0.944	0.958	0.972	0.981	0.991
nyc02sp2	0.978	0.986	0.991	0.949	0.970	0.979	0.983	0.989	0.991	0.994	0.996	0.998
nyc04sp1	0.799	0.862	0.917	0.476	0.578	0.636	0.680	0.760	0.815	0.879	0.912	0.944
nyc04sp2	0.769	0.836	0.897	0.873	0.910	0.930	0.945	0.972	0.988	1.000	1.000	1.000
nyc05sp1	0.842	0.925	0.959	0.756	0.915	0.956	0.970	0.986	0.993	0.998	0.999	1.000
nyc05sp2	0.954	0.969	0.980	0.937	0.960	0.971	0.978	0.988	0.994	0.998	1.000	1.000
nyc08sp1	0.934	0.959	0.976	0.970	0.980	0.985	0.989	0.994	0.997	1.000	1.000	1.000
nyc08sp2	0.937	0.960	0.977	0.971	0.981	0.986	0.989	0.994	0.997	1.000	1.000	1.000
nyc09sp1	0.951	0.968	0.986	0.253	0.371	0.489	0.591	0.743	0.839	0.923	0.951	0.968
sea01sp1	0.971	0.990	0.999	0.902	0.952	0.972	0.982	0.996	0.999	1.000	1.000	1.000
sea01sp2	0.842	0.901	0.945	0.716	0.793	0.843	0.878	0.925	0.945	0.962	0.971	0.982
sea01sp3	0.962	0.993	1.000	0.792	0.912	0.963	0.983	0.998	1.000	1.000	1.000	1.000
sea02sp1	0.824	0.888	0.935	0.488	0.611	0.694	0.752	0.843	0.895	0.944	0.965	0.983
sea02sp2	0.949	0.969	0.984	0.892	0.929	0.949	0.962	0.977	0.984	0.990	0.994	0.997
sea02sp3	0.992	0.996	0.998	0.848	0.896	0.923	0.941	0.968	0.983	0.994	0.997	0.999
sea03sp1	0.754	0.829	0.896	0.871	0.912	0.932	0.945	0.966	0.979	0.993	0.999	1.000
sea03sp2	0.935	0.966	0.985	0.299	0.405	0.500	0.578	0.716	0.802	0.893	0.935	0.966
sea04sp1	0.940	0.969	0.988	0.315	0.466	0.593	0.688	0.813	0.867	0.915	0.940	0.969
sea04sp2	0.954	0.974	0.988	0.650	0.820	0.922	0.969	0.989	0.993	0.995	0.997	0.998
sea06sp1	0.900	0.947	0.974	0.886	0.917	0.935	0.946	0.963	0.973	0.986	0.993	0.999
sea06sp2	0.862	0.919	0.966	0.704	0.746	0.771	0.791	0.830	0.858	0.898	0.923	0.953
sea06sp3	0.718	0.798	0.872	0.745	0.814	0.853	0.878	0.916	0.940	0.964	0.976	0.985
sea06sp4	1.000	1.000	1.000	0.219	0.323	0.428	0.540	0.816	0.941	0.991	1.000	1.000
sea07sp1	0.929	0.976	0.998	0.993	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
sea07sp2	0.864	0.924	0.967	0.693	0.863	0.944	0.978	0.998	0.999	1.000	1.000	1.000
sea07sp3	0.900	0.957	0.994	0.827	0.877	0.898	0.913	0.938	0.953	0.972	0.982	0.992
sfo01sp1	0.927	0.991	0.998	0.253	0.354	0.437	0.504	0.629	0.717	0.840	0.927	0.991
sfo01sp2	0.787	0.870	0.927	0.613	0.722	0.786	0.834	0.902	0.927	0.950	0.962	0.979
sfo01sp4	0.881	0.954	0.983	0.381	0.536	0.657	0.746	0.886	0.950	0.987	0.991	0.995
sfo02sp1	0.666	0.803	0.929	0.108	0.166	0.226	0.286	0.411	0.511	0.664	0.764	0.877
sfo02sp3	0.945	0.966	0.978	0.854	0.918	0.946	0.959	0.973	0.978	0.985	0.990	0.996
sfo04sp1	0.795	0.875	0.924	0.908	0.934	0.949	0.960	0.980	0.992	1.000	1.000	1.000
sfo04sp2	0.976	0.987	0.992	0.991	0.994	0.995	0.997	0.998	0.999	1.000	1.000	1.000
sfo05sp1	0.924	0.986	1.000	0.758	0.856	0.925	0.967	0.997	1.000	1.000	1.000	1.000
sfo05sp2	1.000	1.000	1.000	0.937	0.964	0.978	0.987	0.996	0.997	0.999	1.000	1.000
sfo05sp3	0.996	0.998	1.000	0.681	0.830	0.893	0.927	0.964	0.979	0.992	0.996	0.998
sfo05sp4	0.818	0.890	0.941	0.659	0.753	0.819	0.862	0.917	0.941	0.960	0.970	0.981
sfo06sp1	0.998	1.000	1.000	0.245	0.351	0.454	0.540	0.703	0.810	0.946	0.998	1.000
sfo06sp2	0.337	0.600	0.901	0.052	0.080	0.114	0.152	0.250	0.353	0.561	0.740	0.884
sfo07sp1	0.940	0.960	0.976	0.166	0.292	0.437	0.572	0.795	0.894	0.948	0.962	0.974
smf02sp1	0.982	0.988	0.994	0.819	0.890	0.922	0.940	0.960	0.969	0.978	0.982	0.988
smf03sp1	0.294	0.559	0.878	0.772	0.914	0.937	0.951	0.974	0.987	0.997	1.000	1.000
smf03sp2	0.398	0.686	0.907	0.849	0.925	0.943	0.955	0.976	0.988	0.997	1.000	1.000
smf04sp1	0.940	0.968	0.983	0.496	0.672	0.771	0.839	0.930	0.962	0.980	0.988	0.994
smf04sp2	0.934	0.990	1.000	0.723	0.852	0.936	0.975	0.998	1.000	1.000	1.000	1.000
smf04sp3	0.682	0.855	0.987	0.129	0.198	0.269	0.340	0.496	0.626	0.800	0.895	0.974
smf05sp1	0.982	1.000	1.000	0.160	0.242	0.322	0.400	0.566	0.707	0.887	0.982	1.000
smf06sp1	0.855	0.974	1.000	0.284	0.435	0.574	0.680	0.822	0.873	0.921	0.951	0.984
smf06sp2	0.777	0.945	0.998	0.317	0.433	0.519	0.583	0.691	0.763	0.858	0.917	0.981
smf06sp3	0.934	0.988	1.000	0.463	0.576	0.649	0.704	0.793	0.846	0.913	0.953	0.994
smf07sp1	0.988	0.997	1.000	0.089	0.153	0.234	0.319	0.552	0.766	0.952	0.988	0.997
smf08sp1	0.734	0.830	0.901	0.274	0.468	0.605	0.693	0.813	0.869	0.919	0.941	0.963
smf08sp2	0.926	0.952	0.969	0.551	0.685	0.775	0.835	0.908	0.937	0.961	0.973	0.984
smf08sp3	0.946	0.984	0.997	0.560	0.768	0.876	0.932	0.985	0.995	0.999	0.999	1.000
smf09sp1	0.907	0.932	0.954	0.187	0.346	0.494	0.607	0.761	0.827	0.882	0.907	0.932
smf10sp1	0.990	0.993	0.997	0.936	0.962	0.979	0.986	0.993	0.994	0.995	0.996	0.997
smf10sp2	0.989	0.993	0.996	0.215	0.317	0.416	0.514	0.709	0.855	0.972	0.991	0.994
smf11sp1	0.769	0.938	0.998	0.155	0.248	0.343	0.432	0.600	0.705	0.827	0.897	0.967
smf11sp2	1.000	1.000	1.000	0.976	0.990	0.994	0.998	1.000	1.000	1.000	1.000	1.000

space	qBC5000	DAMin	DAMean	DASd	DAMax	CDAMin	CDAMean	CDASd	CDAMax	DSPMin	DSPMean	DSPSd
nyc01sp1	0.999	0.000	0.638	0.307	0.930	0.000	0.788	0.244	0.945	0.000	0.807	0.235
nyc01sp2	1.000	0.000	0.279	0.236	0.775	0.000	0.631	0.215	0.898	0.000	0.702	0.213
nyc02sp1	0.999	0.000	0.329	0.341	0.936	0.000	0.555	0.302	0.949	0.000	0.578	0.275
nyc02sp2	1.000	0.000	0.107	0.220	0.898	0.061	0.363	0.233	0.935	0.077	0.413	0.225
nyc04sp1	0.966	0.000	0.387	0.372	0.942	0.000	0.578	0.331	0.953	-0.060	0.520	0.283
nyc04sp2	1.000	0.000	0.348	0.349	0.921	0.000	0.520	0.333	0.947	0.000	0.517	0.296
nyc05sp1	1.000	0.000	0.697	0.262	0.924	0.000	0.859	0.118	0.946	0.000	0.866	0.097
nyc05sp2	1.000	0.000	0.157	0.238	0.838	0.000	0.440	0.217	0.917	0.000	0.497	0.198
nyc08sp1	1.000	0.000	0.158	0.241	0.876	0.000	0.333	0.268	0.933	0.000	0.354	0.253
nyc08sp2	1.000	0.000	0.153	0.229	0.867	0.000	0.328	0.259	0.928	0.000	0.350	0.243
nyc09sp1	0.986	0.000	0.393	0.282	0.773	0.000	0.659	0.215	0.879	0.000	0.673	0.184
sea01sp1	1.000	0.000	0.239	0.287	0.888	0.000	0.488	0.265	0.923	0.000	0.538	0.256
sea01sp2	0.993	0.000	0.383	0.367	0.915	0.000	0.613	0.267	0.936	0.000	0.589	0.228
sea01sp3	1.000	0.000	0.492	0.250	0.882	0.000	0.708	0.200	0.922	0.000	0.750	0.195
sea02sp1	0.994	0.000	0.469	0.296	0.929	0.000	0.667	0.271	0.941	-0.131	0.652	0.271
sea02sp2	0.999	0.000	0.166	0.255	0.871	0.000	0.389	0.259	0.921	0.000	0.422	0.238
sea02sp3	1.000	0.000	0.079	0.135	0.852	0.000	0.273	0.188	0.910	0.000	0.314	0.194
sea03sp1	1.000	0.000	0.328	0.260	0.850	0.000	0.528	0.227	0.918	0.000	0.525	0.169
sea03sp2	0.985	0.000	0.405	0.194	0.634	0.000	0.630	0.231	0.817	0.000	0.634	0.230
sea04sp1	0.988	0.000	0.305	0.267	0.914	0.000	0.605	0.197	0.936	0.000	0.633	0.170
sea04sp2	0.999	0.000	0.454	0.142	0.892	0.151	0.706	0.092	0.926	0.188	0.742	0.075
sea06sp1	1.000	0.000	0.297	0.307	0.872	0.000	0.513	0.273	0.929	0.000	0.538	0.248
sea06sp2	0.980	0.000	0.428	0.314	0.892	0.000	0.641	0.242	0.925	0.000	0.597	0.224
sea06sp3	0.990	0.004	0.593	0.238	0.936	0.344	0.770	0.138	0.944	-0.490	0.694	0.185
sea06sp4	1.000	0.000	0.407	0.198	0.659	0.000	0.641	0.240	0.817	0.000	0.687	0.253
sea07sp1	1.000	0.000	0.324	0.370	0.902	0.000	0.524	0.325	0.932	0.000	0.555	0.307
sea07sp2	1.000	0.000	0.490	0.130	0.600	0.037	0.734	0.136	0.813	0.046	0.784	0.137
sea07sp3	0.998	0.000	0.578	0.259	0.909	0.000	0.775	0.167	0.935	0.000	0.782	0.148
sfo01sp1	0.998	0.000	0.484	0.238	0.895	0.000	0.693	0.218	0.941	0.000	0.730	0.210
sfo01sp2	0.994	0.000	0.461	0.363	0.945	0.000	0.713	0.268	0.954	0.000	0.695	0.254
sfo01sp4	0.998	0.000	0.557	0.316	0.950	0.000	0.751	0.264	0.968	0.000	0.768	0.257
sfo02sp1	0.974	0.000	0.765	0.199	0.941	0.000	0.869	0.184	0.963	0.000	0.696	0.262
sfo02sp3	1.000	0.000	0.293	0.322	0.925	0.000	0.596	0.256	0.959	0.000	0.646	0.233
sfo04sp1	1.000	0.000	0.498	0.231	0.878	0.379	0.691	0.134	0.947	0.470	0.698	0.089
sfo04sp2	1.000	0.000	0.205	0.318	0.917	0.000	0.426	0.311	0.957	0.000	0.472	0.309
sfo05sp1	1.000	0.000	0.376	0.408	0.964	0.000	0.540	0.371	0.972	0.000	0.573	0.365
sfo05sp2	1.000	0.000	0.013	0.038	0.247	0.002	0.100	0.140	0.581	0.003	0.120	0.164
sfo05sp3	1.000	0.000	0.073	0.063	0.237	0.186	0.368	0.105	0.639	0.232	0.437	0.111
sfo05sp4	0.993	0.000	0.363	0.384	0.965	0.000	0.545	0.357	0.973	0.000	0.531	0.324
sfo06sp1	1.000	0.000	0.460	0.118	0.596	0.333	0.709	0.081	0.794	0.412	0.761	0.072
sfo06sp2	0.934	0.000	0.941	0.079	0.974	0.000	0.960	0.074	0.974	-0.947	0.606	0.221
sfo07sp1	0.985	0.000	0.575	0.239	0.893	0.000	0.784	0.220	0.948	0.000	0.774	0.210
smf02sp1	0.994	0.000	0.059	0.129	0.753	0.000	0.247	0.192	0.906	0.000	0.276	0.173
smf03sp1	1.000	0.000	0.832	0.300	0.962	0.000	0.852	0.306	0.970	0.000	0.748	0.285
smf03sp2	1.000	0.000	0.800	0.306	0.950	0.000	0.832	0.316	0.965	0.000	0.790	0.305
smf04sp1	0.999	0.000	0.374	0.374	0.949	0.000	0.706	0.203	0.966	0.000	0.754	0.160
smf04sp2	1.000	0.000	0.538	0.376	0.952	0.178	0.776	0.203	0.967	0.222	0.822	0.167
smf04sp3	1.000	0.000	0.843	0.153	0.962	0.435	0.921	0.067	0.971	0.042	0.827	0.214
smf05sp1	1.000	0.000	0.586	0.165	0.768	0.000	0.778	0.143	0.880	0.000	0.817	0.142
smf06sp1	1.000	0.000	0.683	0.262	0.917	0.000	0.803	0.256	0.949	0.000	0.817	0.255
smf06sp2	1.000	0.000	0.719	0.257	0.879	0.000	0.813	0.251	0.933	0.000	0.818	0.249
smf06sp3	1.000	0.000	0.536	0.264	0.812	0.012	0.748	0.193	0.908	0.016	0.792	0.177
smf07sp1	1.000	0.000	0.650	0.255	0.964	0.000	0.823	0.200	0.970	0.000	0.854	0.197
smf08sp1	0.983	0.000	0.510	0.307	0.958	0.000	0.758	0.221	0.963	0.000	0.740	0.208
smf08sp2	0.994	0.000	0.318	0.349	0.965	0.000	0.591	0.287	0.965	-0.514	0.610	0.268
smf08sp3	1.000	0.000	0.558	0.328	0.954	0.000	0.795	0.219	0.962	0.000	0.835	0.207
smf09sp1	0.954	0.000	0.393	0.324	0.960	0.147	0.716	0.189	0.964	-0.704	0.673	0.233
smf10sp1	0.999	0.000	0.030	0.092	0.621	0.000	0.209	0.189	0.840	0.000	0.246	0.200
smf10sp2	0.997	0.000	0.513	0.205	0.876	0.000	0.748	0.165	0.933	0.000	0.785	0.157
smf11sp1	0.999	0.000	0.776	0.150	0.950	0.000	0.883	0.113	0.966	0.000	0.875	0.123
smf11sp2	1.000	0.000	0.005	0.035	0.273	0.086	0.179	0.096	0.634	0.108	0.222	0.112

space	DSPMax	UDIsMin	UDIsMean	UDIsSd	UDIsMax	UDIaMin	UDIaMean	UDIaSd	UDIaMax	UDIeMin	UDIeMean	UDIeSd
nyc01sp1	0.944	0.000	0.064	0.044	0.616	0.000	0.820	0.237	0.951	0.000	0.050	0.099
nyc01sp2	0.919	0.000	0.104	0.117	0.878	0.000	0.860	0.193	0.947	0.000	0.003	0.005
nyc02sp1	0.935	0.000	0.237	0.262	1.000	0.000	0.700	0.269	0.946	0.000	0.040	0.093
nyc02sp2	0.942	0.047	0.372	0.296	1.000	0.000	0.613	0.289	0.950	0.000	0.011	0.043
nyc04sp1	0.909	0.000	0.127	0.152	0.947	0.000	0.661	0.295	0.946	0.000	0.091	0.159
nyc04sp2	0.904	0.000	0.252	0.280	1.000	0.000	0.582	0.304	0.934	0.000	0.065	0.118
nyc05sp1	0.945	0.000	0.056	0.018	0.200	0.000	0.900	0.075	0.953	0.000	0.042	0.074
nyc05sp2	0.866	0.000	0.279	0.189	0.996	0.000	0.702	0.187	0.937	0.000	0.010	0.031
nyc08sp1	0.863	0.000	0.477	0.333	1.000	0.000	0.430	0.308	0.896	0.000	0.020	0.078
nyc08sp2	0.855	0.000	0.481	0.312	1.000	0.000	0.432	0.288	0.895	0.000	0.019	0.073
nyc09sp1	0.849	0.000	0.138	0.127	1.000	0.000	0.786	0.193	0.910	0.000	0.037	0.050
sea01sp1	0.920	0.000	0.279	0.231	1.000	0.000	0.670	0.251	0.933	0.000	0.017	0.069
sea01sp2	0.891	0.000	0.162	0.123	1.000	0.000	0.716	0.204	0.911	0.000	0.084	0.163
sea01sp3	0.920	0.000	0.108	0.052	0.278	0.000	0.827	0.195	0.934	0.000	0.016	0.054
sea02sp1	0.922	0.000	0.099	0.076	0.952	0.000	0.736	0.278	0.926	0.000	0.063	0.136
sea02sp2	0.882	0.000	0.350	0.245	0.995	0.000	0.566	0.254	0.899	0.000	0.021	0.066
sea02sp3	0.832	0.000	0.527	0.269	1.000	0.000	0.415	0.252	0.886	0.000	0.004	0.019
sea03sp1	0.762	0.000	0.313	0.209	1.000	0.000	0.596	0.177	0.868	0.000	0.059	0.099
sea03sp2	0.849	0.000	0.178	0.207	1.000	0.000	0.737	0.248	0.905	0.000	0.043	0.037
sea04sp1	0.920	0.000	0.156	0.091	0.728	0.000	0.778	0.157	0.933	0.000	0.042	0.094
sea04sp2	0.864	0.055	0.128	0.058	0.731	0.264	0.855	0.061	0.920	0.000	0.015	0.039
sea06sp1	0.897	0.000	0.295	0.221	1.000	0.000	0.648	0.214	0.918	0.000	0.036	0.087
sea06sp2	0.891	0.000	0.187	0.160	0.998	0.000	0.700	0.189	0.921	0.000	0.092	0.156
sea06sp3	0.891	0.052	0.112	0.069	0.355	0.130	0.769	0.156	0.922	0.000	0.118	0.183
sea06sp4	0.850	0.000	0.106	0.045	0.236	0.000	0.779	0.282	0.910	0.000	0.000	0.000
sea07sp1	0.924	0.000	0.245	0.266	1.000	0.000	0.642	0.301	0.936	0.000	0.039	0.093
sea07sp2	0.854	0.082	0.125	0.146	1.000	0.000	0.864	0.143	0.902	0.000	0.011	0.005
sea07sp3	0.924	0.000	0.088	0.036	0.248	0.000	0.824	0.167	0.936	0.000	0.063	0.119
sfo01sp1	0.943	0.000	0.133	0.145	1.000	0.000	0.822	0.188	0.942	0.000	0.020	0.046
sfo01sp2	0.943	0.000	0.081	0.155	1.000	0.000	0.771	0.284	0.948	0.000	0.087	0.164
sfo01sp4	0.964	0.000	0.076	0.158	1.000	0.000	0.810	0.271	0.973	0.000	0.053	0.112
sfo02sp1	0.958	0.000	0.043	0.089	1.000	0.000	0.702	0.235	0.958	0.000	0.223	0.202
sfo02sp3	0.953	0.000	0.132	0.144	0.928	0.000	0.806	0.213	0.971	0.000	0.021	0.053
sfo04sp1	0.875	0.026	0.218	0.138	0.388	0.611	0.736	0.098	0.941	0.000	0.045	0.087
sfo04sp2	0.936	0.000	0.363	0.337	1.000	0.000	0.593	0.346	0.970	0.000	0.005	0.022
sfo05sp1	0.968	0.000	0.355	0.402	1.000	0.000	0.603	0.392	0.973	0.000	0.033	0.109
sfo05sp2	0.657	0.104	0.861	0.267	1.000	0.000	0.138	0.266	0.891	0.000	0.000	0.001
sfo05sp3	0.702	0.071	0.277	0.165	0.737	0.258	0.715	0.165	0.908	0.000	0.002	0.004
sfo05sp4	0.952	0.000	0.331	0.388	1.000	0.000	0.586	0.362	0.968	0.000	0.069	0.147
sfo06sp1	0.834	0.079	0.123	0.045	0.378	0.618	0.876	0.045	0.921	0.000	0.000	0.000
sfo06sp2	0.969	0.000	0.026	0.003	0.056	0.000	0.439	0.206	0.973	0.000	0.529	0.208
sfo07sp1	0.942	0.000	0.049	0.023	0.199	0.000	0.847	0.223	0.967	0.000	0.040	0.043
smf02sp1	0.817	0.000	0.590	0.318	1.000	0.000	0.377	0.292	0.938	0.000	0.014	0.044
smf03sp1	0.967	0.000	0.025	0.009	0.047	0.000	0.590	0.264	0.970	0.000	0.271	0.186
smf03sp2	0.964	0.000	0.025	0.010	0.055	0.000	0.689	0.276	0.970	0.000	0.160	0.107
smf04sp1	0.942	0.000	0.071	0.041	0.681	0.000	0.900	0.081	0.960	0.000	0.029	0.080
smf04sp2	0.962	0.027	0.073	0.067	0.561	0.431	0.900	0.093	0.971	0.000	0.026	0.079
smf04sp3	0.965	0.027	0.036	0.016	0.168	0.190	0.747	0.267	0.970	0.000	0.217	0.274
smf05sp1	0.903	0.000	0.080	0.037	0.784	0.000	0.896	0.142	0.941	0.000	0.000	0.001
smf06sp1	0.955	0.000	0.088	0.187	1.000	0.000	0.803	0.251	0.968	0.000	0.064	0.066
smf06sp2	0.936	0.000	0.067	0.124	1.000	0.000	0.773	0.251	0.951	0.000	0.096	0.118
smf06sp3	0.924	0.044	0.110	0.135	1.000	0.000	0.856	0.135	0.948	0.000	0.032	0.063
smf07sp1	0.966	0.000	0.042	0.017	0.127	0.000	0.908	0.201	0.971	0.000	0.004	0.033
smf08sp1	0.948	0.000	0.042	0.017	0.255	0.000	0.838	0.221	0.961	0.000	0.075	0.130
smf08sp2	0.943	0.000	0.146	0.186	0.999	0.000	0.793	0.225	0.958	0.000	0.038	0.104
smf08sp3	0.959	0.000	0.045	0.022	0.255	0.000	0.887	0.204	0.963	0.000	0.022	0.063
smf09sp1	0.954	0.035	0.077	0.049	0.842	0.060	0.844	0.153	0.963	0.000	0.078	0.162
smf10sp1	0.792	0.000	0.658	0.358	1.000	0.000	0.321	0.343	0.901	0.000	0.005	0.016
smf10sp2	0.910	0.000	0.111	0.160	1.000	0.000	0.879	0.161	0.958	0.000	0.008	0.022
smf11sp1	0.964	0.000	0.046	0.016	0.150	0.000	0.816	0.147	0.971	0.000	0.124	0.123
smf11sp2	0.707	0.125	0.689	0.264	1.000	0.000	0.303	0.265	0.875	0.000	0.000	0.000

space	UDIeMax	nHours4k2	senHours4	maxHours4	q90Hours4	maxArea4k	q90Area4k	sunUnif4k2	nHours1k2	senHours1	maxHours1	q90Hours1
nyc01sp1	0.358	24.000	0.806	22.000	17.200	0.037	0.036	0.000	52.000	1.984	44.000	32.000
nyc01sp2	0.025	290.000	15.432	71.000	56.000	0.143	0.090	0.000	518.000	31.396	126.000	82.600
nyc02sp1	0.529	748.000	60.024	611.000	223.600	0.228	0.127	0.000	1272.000	108.169	896.000	343.600
nyc02sp2	0.390	314.000	15.822	477.000	91.000	0.071	0.038	0.000	421.000	21.642	596.000	117.800
nyc04sp1	0.715	926.000	55.737	460.000	295.400	0.171	0.094	0.000	1584.000	122.889	786.000	475.000
nyc04sp2	0.484	1085.000	120.054	988.000	451.600	0.288	0.188	0.000	1689.000	201.136	1462.000	762.000
nyc05sp1	0.364	636.000	41.983	464.000	155.200	0.225	0.097	0.000	935.000	66.709	587.000	215.000
nyc05sp2	0.199	529.000	31.977	355.000	152.000	0.122	0.077	0.000	678.000	40.520	442.000	186.000
nyc08sp1	0.468	463.000	29.553	873.000	247.900	0.132	0.080	0.000	674.000	45.078	1148.000	326.000
nyc08sp2	0.436	460.000	29.713	896.000	222.200	0.129	0.080	0.000	708.000	46.615	1213.000	311.000
nyc09sp1	0.142	311.000	21.723	492.000	81.000	0.157	0.086	0.000	370.000	26.208	694.000	98.000
sea01sp1	0.439	4.000	1.434	59.000	38.000	0.022	0.017	0.000	5.000	2.093	79.000	44.000
sea01sp2	0.669	682.000	68.424	660.000	416.200	0.347	0.189	0.000	1005.000	126.256	961.000	506.200
sea01sp3	0.304	5.000	0.414	20.000	10.800	0.039	0.021	0.000	42.000	2.620	42.000	13.000
sea02sp1	0.750	905.000	64.654	754.000	174.000	0.333	0.136	0.000	1348.000	115.417	1037.000	285.100
sea02sp2	0.414	438.000	24.479	595.000	110.000	0.143	0.054	0.000	747.000	44.577	850.000	162.000
sea02sp3	0.278	483.000	35.557	659.000	84.600	0.294	0.088	0.000	829.000	71.234	1011.000	171.200
sea03sp1	0.337	974.000	116.733	761.000	517.400	0.507	0.244	0.000	1414.000	201.942	1059.000	655.000
sea03sp2	0.119	322.000	12.969	70.000	44.000	0.059	0.040	0.000	366.000	15.143	79.000	51.400
sea04sp1	0.638	326.000	18.788	1737.000	49.000	0.088	0.039	0.000	502.000	28.421	2025.000	65.000
sea04sp2	0.465	126.000	11.566	383.000	63.500	0.246	0.067	0.000	349.000	35.060	546.000	132.000
sea06sp1	0.490	359.000	45.815	505.000	207.000	0.346	0.254	0.000	559.000	78.426	733.000	345.200
sea06sp2	0.596	106.000	8.038	371.000	62.000	0.179	0.030	0.000	247.000	20.577	508.000	117.900
sea06sp3	0.818	1004.000	151.927	1039.000	357.000	0.553	0.313	0.000	1416.000	242.258	1572.000	507.300
sea06sp4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	NA	0.000	0.000	0.000	0.000
sea07sp1	0.355	0.000	0.000	0.000	0.000	0.000	0.000	NA	0.000	0.000	0.000	0.000
sea07sp2	0.025	164.000	17.971	193.000	51.000	0.658	0.149	0.000	606.000	181.867	539.000	302.200
sea07sp3	0.457	69.000	3.188	59.000	36.300	0.046	0.026	0.000	108.000	4.831	79.000	54.000
sfo01sp1	0.347	0.000	1.231	184.000	75.000	0.017	0.010	0.000	26.000	3.718	281.000	131.300
sfo01sp2	0.637	1519.000	105.145	1212.000	496.600	0.185	0.110	0.000	1827.000	143.316	1393.000	516.000
sfo01sp4	0.542	398.000	21.483	511.000	168.500	0.114	0.066	0.000	610.000	34.524	733.000	242.000
sfo02sp1	0.637	552.000	29.829	363.000	120.000	0.172	0.055	0.000	866.000	50.676	485.000	158.000
sfo02sp3	0.361	546.000	29.794	350.000	158.800	0.173	0.054	0.000	757.000	43.952	459.000	177.800
sfo04sp1	0.336	805.000	87.015	879.000	426.000	0.494	0.209	0.000	1140.000	163.915	1181.000	478.400
sfo04sp2	0.199	174.000	10.863	135.000	121.100	0.105	0.088	0.000	331.000	19.874	264.000	194.900
sfo05sp1	0.748	0.000	0.210	33.000	33.000	0.008	0.008	0.000	0.000	0.552	121.000	92.700
sfo05sp2	0.013	0.000	0.000	0.000	0.000	0.000	0.000	NA	12.000	1.230	64.000	33.000
sfo05sp3	0.027	16.000	0.997	28.000	15.200	0.085	0.068	0.000	31.000	1.832	48.000	28.300
sfo05sp4	0.664	950.000	79.733	1145.000	440.200	0.221	0.137	0.000	1245.000	107.179	1423.000	552.400
sfo06sp1	0.000	0.000	0.034	11.000	8.000	0.001	0.001	0.000	0.000	0.036	11.000	8.000
sfo06sp2	0.970	1288.000	113.102	266.000	194.000	0.153	0.125	0.000	1672.000	138.262	298.000	221.000
sfo07sp1	0.205	503.000	35.133	258.000	108.000	0.136	0.035	0.000	734.000	50.355	297.000	127.100
smf02sp1	0.313	0.000	0.000	0.000	0.000	0.000	0.000	NA	691.000	37.240	713.000	391.000
smf03sp1	0.746	1279.000	89.900	231.000	199.000	0.203	0.128	0.000	1570.000	114.550	278.000	230.100
smf03sp2	0.449	1316.000	88.860	234.000	197.000	0.206	0.118	0.000	1615.000	113.614	279.000	226.600
smf04sp1	0.572	485.000	25.010	1166.000	280.200	0.089	0.036	0.000	633.000	32.396	1261.000	209.000
smf04sp2	0.470	0.000	0.000	0.000	0.000	0.000	0.000	NA	0.000	0.013	2.000	1.000
smf04sp3	0.782	0.000	0.000	0.000	0.000	0.000	0.000	NA	0.000	0.010	1.000	1.000
smf05sp1	0.027	0.000	0.000	0.000	0.000	0.000	0.000	NA	0.000	0.000	0.000	0.000
smf06sp1	0.304	4.000	0.296	3.000	2.000	0.029	0.018	0.000	5.000	0.346	3.000	2.000
smf06sp2	0.398	85.000	5.048	99.000	39.000	0.141	0.071	0.000	225.000	20.430	144.000	68.000
smf06sp3	0.241	0.000	0.000	0.000	0.000	0.000	0.000	NA	0.000	0.000	0.000	0.000
smf07sp1	0.783	31.000	1.688	50.000	20.000	0.106	0.048	0.000	138.000	11.334	91.000	27.000
smf08sp1	0.534	1595.000	160.525	1097.000	762.200	0.419	0.206	0.000	2057.000	231.779	1387.000	917.900
smf08sp2	0.806	854.000	51.451	1012.000	273.300	0.145	0.073	0.000	1194.000	73.619	1356.000	319.100
smf08sp3	0.405	71.000	3.283	76.000	68.800	0.058	0.058	0.000	110.000	5.209	128.000	106.000
smf09sp1	0.905	1087.000	74.612	2100.000	309.400	0.132	0.076	0.000	1487.000	100.520	2400.000	370.400
smf10sp1	0.095	4.000	2.738	122.000	75.000	0.024	0.016	0.000	405.000	18.697	327.000	184.300
smf10sp2	0.118	4.000	2.737	122.000	75.000	0.024	0.016	0.000	405.000	18.690	326.000	184.300
smf11sp1	0.488	0.000	0.010	22.000	18.000	0.001	0.001	0.000	0.000	0.035	72.000	20.000
smf11sp2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	NA	0.000	0.000	0.000	0.000

space	maxArea1k	q90Area1k	sunUnif1k2
nyc01sp1	0.038	0.036	0.000
nyc01sp2	0.169	0.097	0.000
nyc02sp1	0.228	0.133	0.000
nyc02sp2	0.071	0.039	0.000
nyc04sp1	0.223	0.137	0.000
nyc04sp2	0.339	0.231	0.000
nyc05sp1	0.226	0.104	0.000
nyc05sp2	0.122	0.076	0.000
nyc08sp1	0.143	0.081	0.000
nyc08sp2	0.139	0.083	0.000
nyc09sp1	0.157	0.083	0.000
sea01sp1	0.027	0.016	0.000
sea01sp2	0.564	0.257	0.000
sea01sp3	0.220	0.060	0.000
sea02sp1	0.333	0.179	0.000
sea02sp2	0.143	0.070	0.000
sea02sp3	0.305	0.139	0.000
sea03sp1	0.518	0.320	0.000
sea03sp2	0.059	0.040	0.000
sea04sp1	0.092	0.046	0.000
sea04sp2	0.386	0.128	0.000
sea06sp1	0.346	0.270	0.000
sea06sp2	0.243	0.073	0.000
sea06sp3	0.587	0.336	0.000
sea06sp4	0.000	0.000	NA
sea07sp1	0.000	0.000	NA
sea07sp2	0.834	0.678	0.000
sea07sp3	0.046	0.032	0.000
sfo01sp1	0.024	0.017	0.000
sfo01sp2	0.239	0.124	0.000
sfo01sp4	0.129	0.073	0.000
sfo02sp1	0.182	0.072	0.000
sfo02sp3	0.181	0.067	0.000
sfo04sp1	0.703	0.305	0.000
sfo04sp2	0.105	0.084	0.000
sfo05sp1	0.008	0.008	0.000
sfo05sp2	0.041	0.021	0.000
sfo05sp3	0.085	0.068	0.000
sfo05sp4	0.221	0.142	0.000
sfo06sp1	0.001	0.001	0.000
sfo06sp2	0.153	0.125	0.000
sfo07sp1	0.143	0.044	0.000
smf02sp1	0.110	0.059	0.000
smf03sp1	0.203	0.131	0.000
smf03sp2	0.206	0.121	0.000
smf04sp1	0.090	0.042	0.000
smf04sp2	0.009	0.006	0.000
smf04sp3	0.009	0.008	0.000
smf05sp1	0.000	0.000	NA
smf06sp1	0.031	0.018	0.000
smf06sp2	0.353	0.161	0.000
smf06sp3	0.000	0.000	NA
smf07sp1	0.193	0.143	0.000
smf08sp1	0.457	0.236	0.000
smf08sp2	0.160	0.078	0.000
smf08sp3	0.058	0.056	0.000
smf09sp1	0.132	0.082	0.000
smf10sp1	0.057	0.038	0.000
smf10sp2	0.057	0.038	0.000
smf11sp1	0.001	0.001	0.000
smf11sp2	0.000	0.000	NA

APPENDIX C: Simulation Methods

C-1 Software Choice Memo

The memo reproduced below outlines the original process of selecting the first simulation tool method.

Sept 7, 2007

MEMO

To: Michael Seaman, CEC

Cc: 0702d Project Team, and Interested parties

From: Abhijeet Pande

Re: **PIER Daylighting Plus, Task 4: Daylighting Metrics, 0702d Simulation Software Choice**

1. DAYLIGHTING METRICS PROJECT OVERVIEW

The use of daylight is increasingly recognized as an essential energy efficiency and demand reduction strategy. However, good or sufficient daylight quality is not well defined, and therefore it difficult to specify in buildings. The dynamic nature of daylight has made it difficult to quantify until the recent advent of powerful computers that can handle annual hourly simulations. Currently, the most widely referrenced current metric (daylight factor) does not address many important variables, including sunny conditions and variation in climate, orientation or location. This project seeks to create a new, widely accepted, set of dynamic daylight performance metrics and criteria, that can be referenced in codes, standards and voluntary programs, and thus vastly accelerate the successful application of daylighting in commercial buildings.

The project team will visit a sample of three daylit spaces types, and create both a qualitative assessment and quantitative annual performance analysis for each space. This memo discusses the choice of tool to be used for the quantitative annual performance analysis for each study space. Analysis will be by individual space, not by building.

1.1 Need for Simulation Tool

The project requires an objective, quantitative analysis of all study spaces with respect to daylight quantity and quality. This analysis needs to be conducted across different climates, space types and geometries, and fenestration choices using standardized set of analysis parameters on an annual basis. The expected outcome is one or more quantitative, numerical metrics of daylight performance in a given space. Computer-based annual hourly simulations of daylight intensity and distribution using site and space specific data collected from the study spaces is the best method for achieving this objective.

Radiance is currently the most detailed and validated lighting and daylighting analysis tool. However, it is not an annual simulation tool: it only runs analysis for one point in time. There are currently two software programs that use Radiance to generate daylight distribution patterns in a space and then process annual weather files to automate an annual analysis of daylight availability and quality: 1.) SPOT, developed by Architectural Energy Corporation through California Energy Commission PIER grants; and 2.) Daysim, developed by Natural Resources Canada.

In selecting a tool (or set of tools) we are determining the level of resolution and quality of our analysis, the likely budget impacts, the ease of replication by other researchers, and the likely standards of analysis which others may need to meet in order to make use of the resulting metrics. In general, our preference is for selecting the most detailed and validated tool(s) at this point (within budget and technology constraints), with the understanding that the level of analysis needed to generate the metrics in the future is more likely to be simplified.

2. SIMULATION TOOL PERFORMANCE REQUIREMENTS

There are key performance metrics that the daylighting simulation tool must be able to perform in order to be useful for the Daylight Metrics project. Below is a brief summary of these capabilities:

- *Annual Analysis*: the tool should be capable of predicting daylight on an hourly (or sub-hourly) basis for the entire year using standard local weather files (TMY2 or equivilant).
- *Parametric abilities*: We anticipate that the project would analyze several spaces in different locations and under different climate conditions. As such the tool should be able to parameterize the analysis using all the analysis variables described below.
- *Luminance vs. Illuminance*: the daylighting simulation tool should be able to report both illuminance distribution at task and room surfaces as well as luminance distributions, especially around windows and skylights to enable glare analysis.
- *Locations/Daylighting Conditions*: the tool should be able to model daylighting conditions for numerous locations in the USA, including California, New York, Oregon, Washington and Idaho. The tool should be able to handle variations in daylight and sky conditions (clear, overcast, partially overcast) in these locations which is essential to develop a metric that works across the different climates.
- *Building/Space Types Modeled*: The tool should be able to model commonly found daylighting configurations and spaces including libraries, gymnasiums, warehouses, retail spaces, offices, classrooms and other commercial spaces. This includes spaces with curved surfaces and sloped roofs. Reflectances of normal construction surfaces should be capable of being modeled. Specular surfaces will be avoided. It would be good, but not essential, to specify more than one reflectance area per wall or floor surface.
- *Fenestration Types*: The tool should be able to model commonly used glazing materials and fenestration designs such as windows, clerestories, skylights, light

wells. Special glazings with variable optics (by geometry or solar intensity) are not expected to be modeled at this time.

- *Fenestration controls*: The tool should be able to model common fenestration controls such as manually-operated blinds, shades and curtains, fixed exterior shading, and light shelves. Automated interior or exterior sun or glare controls would be excellent, but not expected at this point. Specially shaped light redirecting devices are not expected to be modeled for this study.
- *Operating Schedules*: The tool should be able to model the occupant, fenestration control and electric lighting schedules in a given study space. These schedules will vary by space, and as such the tool should allow the flexibility to use custom schedules.
- *Data Outputs*: the outputs of most importance to this project are the hourly or sub-hourly illuminance and luminance values at several key locations in the study space. Ideally the information can be provided on one foot grids, but four foot grids could be acceptable. The tool should have the capability to export such values in a format easily editable by Excel or similar analysis tools.
- *Energy Impacts Analysis*: It is the intent of the project to also assess the energy use impacts of any design, including electric lighting, heating, cooling and ventilation. Thus the tool should either provide this capability, or provide export data that can easily be imported into DOE2 or similar energy simulation engine.
- *Ease of Use and Analysis time*: We anticipate conducting analysis on several spaces using various parametric inputs, and the total number of simulations will likely run into the hundreds. As such the time required for data entry, simulation and data export from the tool, as well as the ease of making changes across several models, is critical for the project schedule and budget.

2.1 Daysim Capabilities and Limitations

DAYSIM is a daylighting analysis software that calculates the annual daylight availability in buildings, as well as the lighting energy use of automated lighting controls (occupancy sensors, photocells) compared to standard on/off switches.

Daysim combines the backward ray tracing software Radiance, developed by Greg Ward at the Lawrence Berkeley National Laboratory, with a daylight-coefficients approach. The underlying sky model to calculate annual illuminance profiles is the Perez all weather sky model. A stochastic model from Skartveit and Olseth has been adapted to mimic the short-time-step dynamics of indoor illuminances based on hourly mean direct and diffuse irradiances. Annual illuminance profiles are coupled with user occupancy data to predict the annual use of electric lighting in a building zone depending on the lighting and blind control strategy. The underlying Lightswitch manual lighting control model is based on monitored occupancy behavior from several field studies.

Key capabilities of Daysim include:

- Ability to calculate both luminance and illuminance values -

Daysim is the only commercially available tool that can calculate both luminance and illuminance calculations in a single space. Thus, it can predict available daylight at various locations in the space as well as the brightness of the window in relation to those locations.

- Ecotect interface for data entry and export of Radiance –

  Daysim has been linked to the popular Ecotect building design software. Ecotect models can be directly exported to Daysim for further analysis. Vice versa, Daysim results can be imported back into Ecotect for presentation.

  This link to Ecotect provides for a designer friendly method to input building data including complex geometries such as clerestories, skylights, roof monitors, curved walls, sloped ceilings and other non-orthogonal building features.

- Parametric capabilities -

  Daysim, through its binaries, allows for parametric analysis of multiple variables. The parametric variables can be set in command-line mode using a Linux installation of Daysim, and the analysis conducted using command-line instructions. This significantly speeds up the process of simulating a large number of models at once, as well as conducting parametric analysis on various factors in all the models.

- Various daylight metrics implemented and hourly/sub-hourly reports available

  Daysim has fully implemented daylight metrics that are currently in use such as Daylight Factor, Daylight Autonomy, Continuous Daylight Autonomy, Useful Daylight Illuminance among others. Other metrics can be added on an as-needed basis, by re-processing the raw output data.

  Reporting is available as both delimited text files and graphical representations. In addition, results from Daysim can be imported into the Ecotect model to view the impact in a graphical format.

- Validation:

  Daylight calculation engine extensively validated. Daysim binaries for calculating daylight coefficients also extensively validated.

Limitations or concerns:

- Energy calculations –

  Ecotect provides hourly calculation of space temperatures and heating/cooling loads in the space due to the space geometry, materials and fenestration. Ecotect includes a fairly detailed library of materials that have associated thermal properties such as thickness, density, specific heat and resistance in order to calculate the heating and cooling loads.

  For the purpose of this project, knowing the impact of fenestration on heating and cooling loads is more important than knowing how the HVAC system selection will affect energy use, which is currently not possible within Ecotect.

  Ecotect can however export building geometry and thermal zoning data into an .INP file that can be imported into eQuest or other DOE-2 based programs. It also generates similar input files for EnergyPlus. Thus any additional analysis that may require the full capabilities of these simulation programs can be achieved without having to recreate the model from scratch in these programs.

- Expertise needed for Ecotect and Radiance for analysis

  To use Ecotect and Daysim/Radiance requires a fair bit of expertise in three dimensional modeling, as well as knowledge of the Daysim/Radiance binaries. The project team does possess these skills however, and this should not be an issue for this particular project.

2.2 SPOT Capabilities and Limitations

The Sensor Placement + Optimization Tool or SPOT™ is intended to assist a designer in quantifying the existing or intended electric lighting and annual daylighting characteristics of a given space and to help establish the optimal photosensor placement for the space relative to annual performance and annual energy savings.

SPOT™ was developed with classroom daylighting in mind, but can be used for other types of spaces. SPOT™ handles both top and side daylight sources within simple geometries and can model any electric lighting source. It uses Radiance as a pre-processor of daylight distribution for a sample set of conditions, and then generates annual reports of performance using pre-formatted Excel reporting.

Key capabilities of SPOT include:

- Modeling of daylight sensor performance is main objective -

  The primary purpose of SPOT is to be able to predict the impact of the relative position of daylighting sensors in the space. This enables the building or lighting designer to optimize the location of the sensor in order to maximize daylighting savings.

- Easy-to-use interface -

  SPOT uses a simple Excel-based interface for data entry. Most data entry is sequential with the calculations broken into several discreet steps.

  After each data entry step, there is a calculation done by the software to generate the next level of analysis.

- Various daylighting metrics calculated –

  Various CHPS and LEED daylighting metrics have been recently added to the tool, calculating the required criteria and generating a printable report.

- Simplified analysis and report format for daylight metrics currently implemented

  SPOT provides an easy to understand report on various aspects of the lighting and daylighting design of the space through a graphical UI.

- Energy Analysis

  Similar to Ecotect, SPOT can generate heating and cooling load impacts of the daylighting design. Unlike Ecotect however, it does not include material thermal properties in it's calculations, instead using simplified DOE2-based assumptions to predict annual energy impacts of a daylighting design.

Limitations and concerns:

- GUI restricts geometry to simple rectangle –

  Since the data entry is done using an Excel interface, the space dimensions are limited to that of a rectangle. The model works only for a square/rectangular space with four walls and a flat roof. This works for simpler spaces such as portable classrooms and small private offices. However, most daylit building have features such as roof monitors, sloped or curved surfaces, internal partitions, etc., which cannot currently be modeled in SPOT.

  A version of SPOT with expanded geometric capabilities is reportedly in the works, but will not be ready in time for this project.

- Output options for hourly/sub-hourly results limited

  SPOT does not conduct a true hourly/sub-hourly annual analysis. It uses key months and times of day as design-day calculations and then provides a summary report of those design days.

- Sky model used in SPOT –

  SPOT uses the CIE sky model method recommended by IESNA. This calculation method uses a combination of direct illumination (illumination from the 5 degree circumsolar zone) and diffuse illumination (sky illuminance) to weigh sunny and cloudy conditions. Per the software authors, this method provides comparable results on an annual basis to the Perez sky model and daylight coefficients method used in Daysim, but the specific values for a given day/hour particularly under partly cloudy skies will not be accurate.

- Validation:

  Since SPOT is still under development and improvements are being made to the tool, it is as yet not a validated tool against other similar software or against field data. In time such validations may be done, but that would not happen in time for this project.

- Parametric analysis –

  SPOT currently does not have any parametric capabilities which would allow easy comparison of design options and climates. Comparing alternative locations or orientations would require generating a new model, which is quite time intensive.

- Energy calculations –

  While SPOT provides a energy impacts analysis, it is done in a simplified fashion that cannot account for the variations in geometrics or operation that may be important in our study spaces.

3. PROPOSED SIMULATION TOOL AND APPROACH

3.1 Ecotech/Radiance/Daysim as the illumination simulation software

Performance metrics for the daylighting simulation software are outlined earlier in this report in Section 2.

Key of these is the ability to model the various types of spaces studied for the project, and to provide meaningful hourly/sub-hourly results that can be compared using statistical methods for illumination and luminance in space. Also key is to be able to parametrically analyze impact of certain building features that can affect the daylight quality and daylight metric.

On each of these three counts, the combined Ecotech/Radiance/Daysim approach provides better capabilities, speed of calculations and accuracy of results as compared to the SPOT/Radiance approach. While SPOT provides a very useful tool for analyzing daylighting performance for simple spaces and predicting electric lighting savings due to the photosensor performance, we do not feel that it provides sufficient flexibility or ease of modification for this particular project.

We therefore propose to use the Ecotech/Radiance/Daysim approach for the simulation studies to be conducted for this project, with a secondary energy analysis in eQuest (if needed) for each study space. The following sections are based on this recommendation.

3.2 Proposed Simulation Methodology

The team proposes a methodology for conducting the daylighting simulations for this project using tools developed and validated at the Natural Resources Canada (NRC). The proposed approach would allow parametric analysis of all study spaces using established procedures that have been extensively used and validated by Dr. Christoph Reinhart at NRC.

Following is a brief description of the approach:

- The analysis, data import and analysis process will be centralized and automated on NRC servers. All analysis files will reside on a central server accessible to all team members. This will ensure data file integrity and reduced possibilities of several versions of the same study space floating around on computers of different team members.
- The analysis will be conducted using Radiance and Daysim binaries in a Linux environment. All analysis will be conducted using command-line scripts already developed by Reinhart and his team. These scripts will allow batch operations and ability to specify parametric inputs for the analysis.
- For each study space to be analyzed, HMG and NEEA team members will generate three-dimensional models using Ecotect. The advantage of Ecotect is that it is a native 3D environment and allows easy export to Daysim and Radiance for daylighting

calculations. Further, Ecotect can read outputs from Daysim and Radiance and allows further data analysis of the results in graphical and tabular format.

- HMG and NEEA team members will generate specifications for reporting sensor locations and type of sensors (illuminance/ luminance, orientation of sensor) in Ecotect.
- All Ecotect models are uploaded to a central FTP site maintained by NRC.
- Reinhart will conduct analysis on imported Ecotect Models in Daysim and Radiance using command line scripts that will automate analysis of all spaces
- Reinhart will provide database of results for further examination and analysis by HMG
- If needed, HMG will export the Ecotect models into eQuest for an energy impact analysis of the daylighting design. Illumination levels from Daysim will provide input to the DOE2 lighting analysis. HMG will use default systems for all energy using equipment in the spaces in order to create comparable output across all study spaces. Defaults for operating schedules will also be used appropriate to each space type.
- Reinhart will run additional parametrics as needed to address questions and improve needed daylight metric

Advantages of this approach:

- *Scalable/ Batch operations*: Using this approach it is easy to conduct analysis for all spaces or a sub-set (say all schools, or all spaces with clerestories) without having to conduct analysis on these spaces individually.
- *Parametric capabilities*: This approach allows us to add analysis variables and to analyze their impact on daylight quality or to look at various daylight metrics across study spaces in a systemic manner without having to conduct analysis on a space-by-space basis.
- *Reduction in data entry errors*: Since all analysis parameters will be common across all study spaces, the possibilities of different data entry errors in different models are limited.
- *Analysis time*: Since all analysis will be conducted in a command-line setting in Linux, the analysis time will be considerable shorter than that required by a windows GUI where visual basic or JavaScript limitations slow down the analysis.

In the long term, and for the general audience, results from this analysis can be easily ported into other simulation tools such as SPOT or others yet to be developed. Thus, the choice of this particular methodology does not hinder the development and improvement of the metrics within other software tools.

C-2 Daylighting Analysis Framework

C-2.1 Basic Framework

This basic framework lists the universe of topics and capabilities that might be included in daylighting performance metric(s), simulation tools, or code requirements

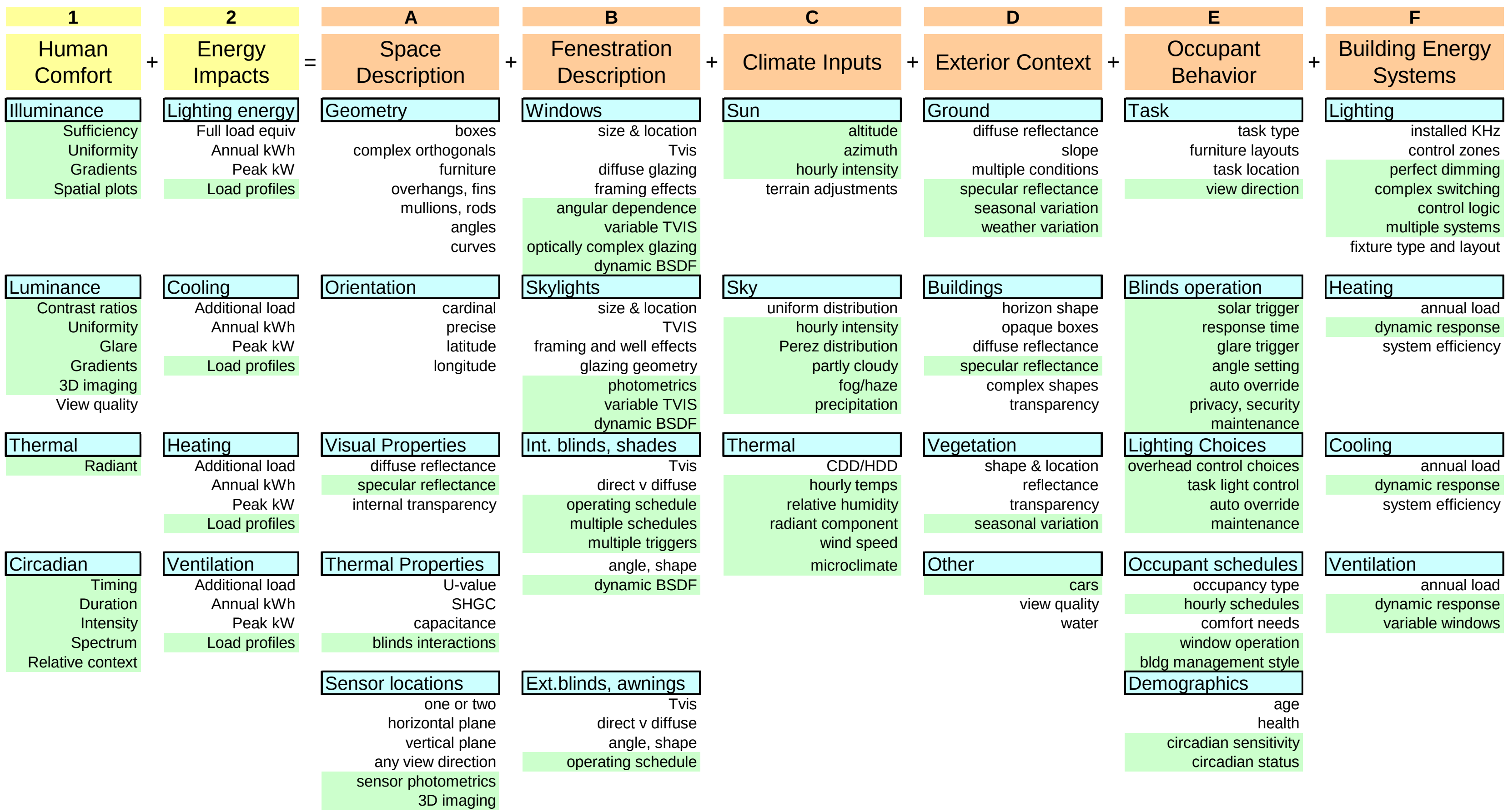
Figure 42: Basic Framework

1	2	A	B	C	D	E	F
Human Comfort +	Energy Impacts =	Space Description +	Fenestration Description +	Climate Inputs +	Exterior Context +	Occupant Behavior +	Building Energy Systems
Illuminance Sufficiency Uniformity Gradients Spatial plots	**Lighting energy** Full load equiv Annual kWh Peak kW Load profiles	**Geometry** boxes complex orthogonals furniture overhangs, fins mullions, rods angles curves	**Windows** size & location Tvis diffuse glazing framing effects angular dependence variable TVIS optically complex glazing dynamic BSDF	**Sun** altitude azimuth hourly intensity terrain adjustments	**Ground** diffuse reflectance slope multiple conditions specular reflectance seasonal variation weather variation	**Task** task type furniture layouts task location view direction	**Lighting** installed KHz control zones perfect dimming complex switching control logic multiple systems fixture type and layout
Luminance Contrast ratios Uniformity Glare Gradients 3D imaging View quality	**Cooling** Additional load Annual kWh Peak kW Load profiles	**Orientation** cardinal precise latitude longitude	**Skylights** size & location Tvis framing and well effects glazing geometry photometrics variable TVIS dynamic BSDF	**Sky** uniform distribution hourly intensity Perez distribution partly cloudy fog/haze precipitation	**Buildings** horizon shape opaque boxes diffuse reflectance specular reflectance complex shapes transparency	**Blinds operation** solar trigger response time glare trigger angle setting auto override privacy, security maintenance	**Heating** annual load dynamic response system efficiency
Thermal Radiant	**Heating** Additional load Annual kWh Peak kW Load profiles	**Visual Properties** diffuse reflectance specular reflectance internal transparency	**Int. blinds, shades** Tvis direct v diffuse operating schedule multiple schedules multiple triggers angle, shape dynamic BSDF	**Thermal** CDD/HDD hourly temps relative humidity radiant component wind speed microclimate	**Vegetation** shape & location reflectance transparency seasonal variation	**Lighting Choices** overhead control choices task light control auto override maintenance	**Cooling** annual load dynamic response system efficiency
Circadian Timing Duration Intensity Spectrum Relative context	**Ventilation** Additional load Annual kWh Peak kW Load profiles	**Thermal Properties** U-value SHGC capacitance blinds interactions			**Other** cars view quality water	**Occupant schedules** occupancy type hourly schedules comfort needs window operation bldg management style	**Ventilation** annual load dynamic response variable windows
		Sensor locations one or two horizontal plane vertical plane any view direction sensor photometrics 3D imaging	**Ext.blinds, awnings** Tvis direct v diffuse angle, shape operating schedule			**Demographics** age health circadian sensitivity circadian status	

C-2.2 Moving Parts

This framework illustrates the number of potentially dynamic components (highlighted in green) to daylighting analysis.

Figure 43: Moving Parts Framework



C-2.3 Daylight Metrics Project Goals

Yellow highlighted cells show those topics and capabilities initially desired for the metrics project.

Figure 44: Project Goals Framework

1	2	A	B	C	D	E	F
Human Comfort	Energy Impacts	Space Description	Fenestration Description	Climate Inputs	Exterior Context	Occupant Behavior	Building Energy Systems
Illuminance Sufficiency Uniformity Gradiants	Lighting energy Full load equiv Annual Kwh Peak KW	Geometry boxes complex orthangonals furniture overhangs, fins mullions, rods angles curves	Windows size & location VLT diffuse glazing multiple orientations angular dependance optically complex glazing dynamic BTDF variable VLT	Sun Altitude Azimuth Hourly Intensity Terrain adjustments	Ground diffuse reflectance slope multiple conditions specular reflectance seasonal variation weather variation	Task task type furniture layouts task location view direction	Lighting Installed Kwh control zones perfect dimming complex switching control logic mutiple systems fixture type and layout
Lumiance Contrast ratios Uniformity Glare Gradiants	Cooling Additional load Annual Kwh Peak KW	Orientation cardinal precise latitude	Skylights size & location VLT geometry photometrics dynamic BTDF variable VLT	Sky Uniform distribution Hourly intensity Perez distribution Partly cloudy Fog/haze Precipitation	Buildings horizon shape opaque boxes diffuse reflectance specular reflectance complex shapes transparency	Blinds operation solar trigger response time glare trigger angle setting auto override privacy, security maintenance	Heating annual load dynamic response
Thermal Radiant	Heating Additional load Annual Kwh Peak KW	Visual Properties diffuse reflectance specular reflectance internal transparency	Int. blinds, shades, etc VLT direct v diffuse operating schedule multiple schedules multiple triggers photometrics (angle, shape) dynamic BTDF	Thermal CDD/HDD hourly temps relative humidity radiant component wind speed adjust for mircoclimate	Vegetation shape & location reflectance transparency seasonal variation	Lighting Choices overhead control choices task light control auto override maintenance	Cooling annual load dynamic response
Circadian Spectrum Intensity Timing Duration Relative context	Ventilation Additional load Annual Kwh Peak KW	Thermal Properties U-value capacitance			Other cars other variable sources?	Occupant schedules occupancy type hourly schedules comfort needs window operation bldg management style	Ventilation annual load dynamic response variable windows
		Sensor locations one or two cont. floor plane any horizontal plane any vertical plane any view direction global assessement	Ext.blinds, awnings, etc VLT direct v diffuse angle, shape operating schedule			Demographics age health circadian sensitivity cirdacian exposure status	

C-2.4 Daylight Metrics Project Constraints

Colored cells show the progression of constraints applied to selecting the methodology employed for the metrics project. Cells highlighted in yellow indicate problems or questions. Cells highlighted in purple indicate aspects eliminated from consideration in 2007 during methodology discussions. Cells highlighted in pink indicate aspects eliminated in 2008 due to project limitations. Cells highlighted in gray indicated aspects beyond the original scope of the project.

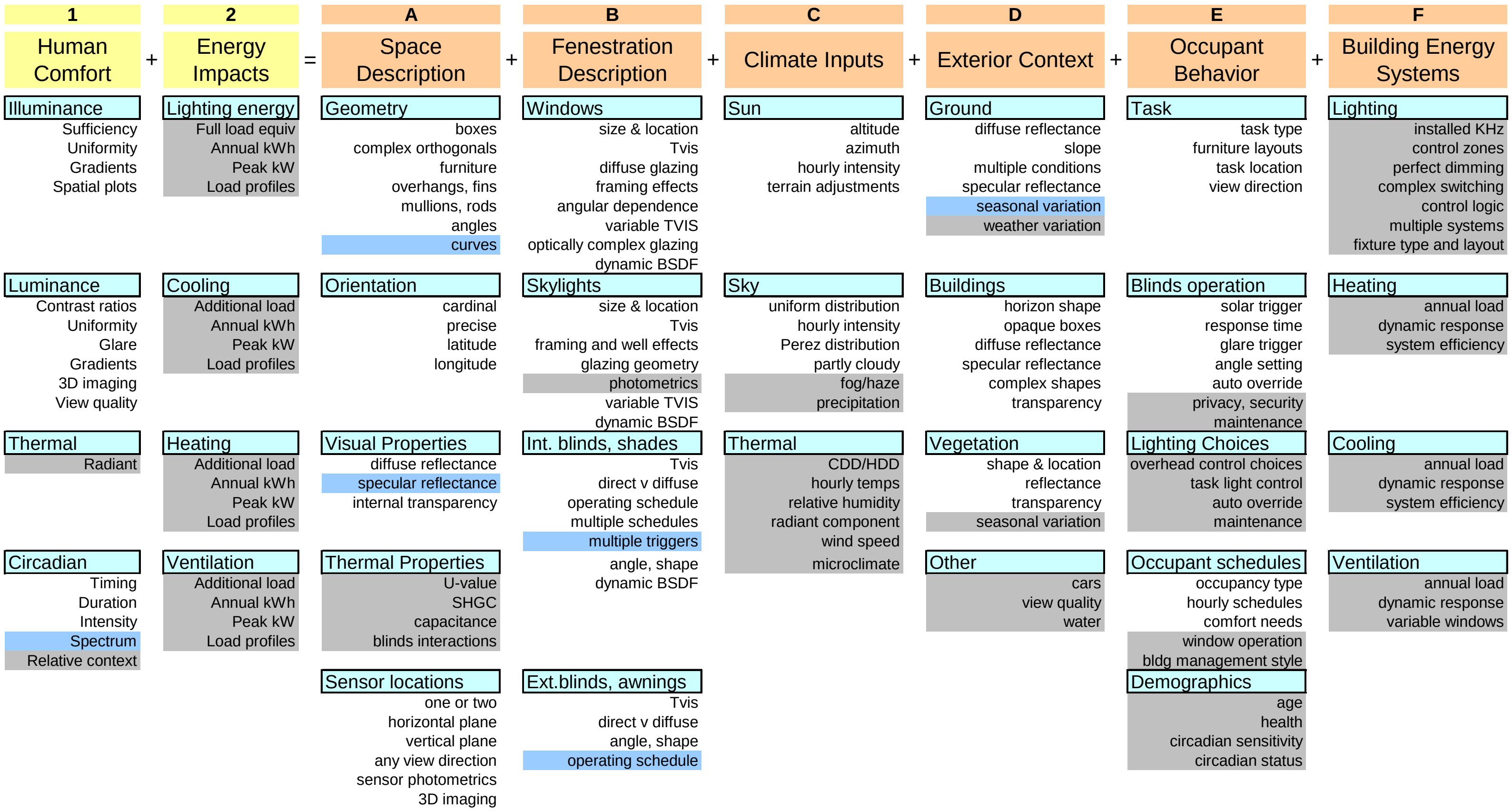
Figure 45: Project Constraints Framework

1 Human Comfort		2 Energy Impacts		A Space Description		B Fenestration Description		C Climate Inputs		D Exterior Context		E Occupant Behavior		F Building Energy Systems
	+		=		+		+		+		+		+	
Illuminance Sufficiency Uniformity Gradiants		**Lighting energy** Full load equiv Annual Kwh Peak KW		**Geometry** boxes complex orthangonals furniture overhangs, fins mullions, rods ceiling geometry, wells angles curves		**Windows** size & location VLT diffuse glazing multiple orientations angular dependance optically complex glazing dynamic BTDF variable VLT		**Sun** Altitude Azimuth Hourly Intensity Terrain adjustments		**Ground** diffuse reflectance slope multiple conditions specular reflectance seasonal variation weather variation		**Task** task type furniture layouts task location view direction		**Lighting** Installed Kwh control zones perfect dimming complex switching control logic mutiple systems fixture type and layout
Lumiance Contrast ratios Uniformity Glare Gradiants		**Cooling** Additional load Annual Kwh Peak KW		**Orientation** cardinal precise latitude		**Skylights** size & location VLT glazing geometry photometrics dynamic BTDF variable VLT		**Sky** Uniform distribution Hourly intensity Perez distribution Partly cloudy Fog/haze Precipitation		**Buildings** horizon shape opaque boxes diffuse reflectance specular reflectance complex surfaces transparency		**Blinds operation** solar trigger response time glare trigger angle setting auto override privacy, security maintenance		**Heating** annual load dynamic response
Thermal Radiant		**Heating** Additional load Annual Kwh Peak KW		**Surface Properties** diffuse reflectance specular reflectance internal transparency multiple conditons		**Int. blinds, shades, etc** VLT direct v diffuse operating schedule multiple schedules multiple triggers photometrics (angle, shape) dynamic BTDF		**Thermal** CDD/HDD hourly temps relative humidity radiant component wind speed adjust for mircoclimate		**Vegetation** shape & location reflectance transparency seasonal variation		**Lighting Choices** overhead control choices task light control auto override maintenance		**Cooling** annual load dynamic response
Circadian Spectrum Intensity Timing Duration Relative context		**Ventilation** Additional load Annual Kwh Peak KW		**Envelope Properties** U-value capacitance						**Other** cars other variable sources?		**Occupant schedules** occupancy type hourly schedules comfort needs window operation bldg management style		**Ventilation** annual load dynamic response variable windows
				Sensor locations one or two cont. floor plane any horizontal plane any vertical plane any view direction global assessement		**Ext.blinds, awnings, etc** VLT direct v diffuse angle, shape operating schedule						**Demographics** age health circadian sensitivity cirdacian exposure status		

C-2.5 Dynamic Radiance (v1)

White cells show the capabilities of Dynamic Radiance. Grayed cells are clearly outside of its capabilities, while blue cells might be achieved with some additional programing.

Figure 46: Dynamic Radiance Framework



C-2.6 Ecotech v5.5

White cells show the capabilities of Ecotech at the time of evalution in 2007. Grayed cells are clearly outside of its capabilities, while blue cells might be achieved with some additional programing.

Figure 47: Ecotect Framework

1		2		A		B		C		D		E		F
Human Comfort	+	Energy Impacts	=	Space Description	+	Fenestration Description	+	Climate Inputs	+	Exterior Context	+	Occupant Behavior	+	Building Energy Systems
Illuminance Sufficiency Uniformity Gradiants		**Lighting energy** Full load equiv Annual Kwh Peak KW		**Geometry** boxes complex orthangonals furniture overhangs, fins mullions, rods angles curves		**Windows** size & location VLT diffuse glazing multiple orientations angular dependance optically complex glazing dynamic BTDF variable VLT		**Sun** Altitude Azimuth Hourly Intensity Terrain adjustments		**Ground** diffuse reflectance slope multiple conditions specular reflectance seasonal variation weather variation		**Task** task type furniture layouts task location view direction		**Lighting** Installed Kwh control zones perfect dimming complex switching control logic mutiple systems fixture type and layout
Lumiance Contrast ratios Uniformity Glare Gradiants		**Cooling** Additional load Annual Kwh Peak KW		**Orientation** cardinal precise latitude		**Skylights** size & location VLT geometry photometrics dynamic BTDF variable VLT		**Sky** Uniform distribution Hourly intensity Perez distribution Partly cloudy Fog/haze Precipitation		**Buildings** horizon shape opaque boxes diffuse reflectance specular reflectance complex shapes transparency		**Blinds operation** solar trigger response time glare trigger angle setting auto override privacy, security maintenance		**Heating** annual load dynamic response
Thermal Radiant		**Heating** Additional load Annual Kwh Peak KW		**Visual Properties** diffuse reflectance specular reflectance internal transparency		**Int. blinds, shades, etc** VLT direct v diffuse operating schedule multiple schedules multiple triggers photometrics (angle, shape) dynamic BTDF		**Thermal** CDD/HDD hourly temps relative humidity radiant component wind speed adjust for mircoclimate		**Vegetation** shape & location reflectance transparency seasonal variation		**Lighting Choices** overhead control choices task light control auto override maintenance		**Cooling** annual load dynamic response
Circadian Spectrum Intensity Timing Duration Relative context		**Ventilation** Additional load Annual Kwh Peak KW		**Thermal Properties** U-value capacitance						**Other** cars other variable sources?		**Occupant schedules** occupancy type hourly schedules comfort needs window operation bldg management style		**Ventilation** annual load dynamic response variable windows
				Sensor locations one or two cont. floor plane any horizontal plane any vertical plane any view direction global assessement		**Ext.blinds, awnings, etc** VLT direct v diffuse angle, shape operating schedule						**Demographics** age health circadian sensitivity cirdacian exposure status		

C-2.7 eQuest, split flux

White cells show the capabilities of eQuest at the time of evalution in 2007. Grayed cells are clearly outside of its capabilities, while blue cells might be achieved with some additional programing.

Figure 48: eQuest Framework

1		2		A		B		C		D		E		F
Human Comfort	+	Energy Impacts	=	Space Description	+	Fenestration Description	+	Climate Inputs	+	Exterior Context	+	Occupant Behavior	+	Building Energy Systems
Illuminance Sufficiency Uniformity Gradiants		**Lighting energy** Full load equiv Annual Kwh Peak KW		**Geometry** boxes complex orthangonals furniture overhangs, fins mullions, rods angles curves		**Windows** size & location VLT diffuse glazing multiple orientations angular dependance optically complex glazing dynamic BTDF variable VLT		**Sun** Altitude Azimuth Hourly Intensity Terrain adjustments		**Ground** diffuse reflectance slope multiple conditions specular reflectance seasonal variation weather variation		**Task** task type furniture layouts task location view direction		**Lighting** Installed Kwh control zones perfect dimming complex switching control logic mutiple systems fixture type and layout
Lumiance Contrast ratios Uniformity Glare Gradiants		**Cooling** Additional load Annual Kwh Peak KW		**Orientation** cardinal precise latitude		**Skylights** size & location VLT geometry photometrics dynamic BTDF variable VLT		**Sky** Uniform distribution Hourly intensity Perez distribution Partly cloudy Fog/haze Precipitation		**Buildings** horizon shape opaque boxes diffuse reflectance specular reflectance complex shapes transparency		**Blinds operation** solar trigger response time glare trigger angle setting auto override privacy, security maintenance		**Heating** annual load dynamic response
Thermal Radiant		**Heating** Additional load Annual Kwh Peak KW		**Visual Properties** diffuse reflectance specular reflectance internal transparency		**Int. blinds, shades, etc** VLT direct v diffuse operating schedule multiple schedules multiple triggers photometrics (angle, shape) dynamic BTDF		**Thermal** CDD/HDD hourly temps relative humidity radiant component wind speed adjust for mircoclimate		**Vegetation** shape & location reflectance transparency seasonal variation		**Lighting Choices** overhead control choices task light control auto override maintenance		**Cooling** annual load dynamic response
Circadian Spectrum Intensity Timing Duration Relative context		**Ventilation** Additional load Annual Kwh Peak KW		**Thermal Properties** U-value capacitance						**Other** cars other variable sources?		**Occupant schedules** occupancy type hourly schedules comfort needs window operation bldg management style		**Ventilation** annual load dynamic response variable windows
				Sensor locations one or two cont. floor plane any horizontal plane any vertical plane any view direction global assessement		**Ext.blinds, awnings, etc** VLT direct v diffuse angle, shape operating schedule						**Demographics** age health circadian sensitivity cirdacian exposure status		

C-2.8Energy Plus, Split Flux

White cells show the capabilities of EnergyPlus with the split flux method at the time of evalution in 2007. Grayed cells are clearly outside of its capabilities, while blue cells might be achieved with some additional programing.

Figure 49: Energy Plus with Split Flux Framework

1 Human Comfort + 2 Energy Impacts = A Space Description + B Fenestration Description + C Climate Inputs + D Exterior Context + E Occupant Behavior + F Building Energy Systems

1 Human Comfort

- Illuminance: Sufficiency, Uniformity, Gradiants
- Lumiance: Contrast ratios, Uniformity, Glare, Gradiants
- Thermal: Radiant
- Circadian: Spectrum, Intensity, Timing, Duration, Relative context

2 Energy Impacts

- Lighting energy: Full load equiv, Annual Kwh, Peak KW
- Cooling: Additional load, Annual Kwh, Peak KW
- Heating: Additional load, Annual Kwh, Peak KW
- Ventilation: Additional load, Annual Kwh, Peak KW

A Space Description

- Geometry: boxes, complex orthangonals, furniture, overhangs, fins, mullions, rods, angles, curves
- Orientation: cardinal, precise, latitude
- Visual Properties: diffuse reflectance, specular reflectance, internal transparency
- Thermal Properties: U-value, capacitance
- Sensor locations: one or two, cont. floor plane, any horizontal plane, any vertical plane, any view direction, global assessement

B Fenestration Description

- Windows: size & location, VLT, diffuse glazing, multiple orientations, angular dependance, optically complex glazing, dynamic BTDF, variable VLT
- Skylights: size & location, VLT, geometry, photometrics, dynamic BTDF, variable VLT
- Int. blinds, shades, etc: VLT, direct v diffuse, operating schedule, multiple schedules, multiple triggers, photometrics (angle, shape), dynamic BTDF
- Ext.blinds, awnings, etc: VLT, direct v diffuse, angle, shape, operating schedule

C Climate Inputs

- Sun: Altitude, Azimuth, Hourly Intensity, Terrain adjustments
- Sky: Uniform distribution, Hourly intensity, Perez distribution, Partly cloudy, Fog/haze, Precipitation
- Thermal: CDD/HDD, hourly temps, relative humidity, radiant component, wind speed, adjust for mircoclimate

D Exterior Context

- Ground: diffuse reflectance, slope, multiple conditions, specular reflectance, seasonal variation, weather variation
- Buildings: horizon shape, opaque boxes, diffuse reflectance, specular reflectance, complex shapes, transparency
- Vegetation: shape & location, reflectance, transparency, seasonal variation
- Other: cars, other variable sources?

E Occupant Behavior

- Task: task type, furniture layouts, task location, view direction
- Blinds operation: solar trigger, response time, glare trigger, angle setting, auto override, privacy, security, maintenance
- Lighting Choices: overhead control choices, task light control, auto override, maintenance
- Occupant schedules: occupancy type, hourly schedules, comfort needs, window operation, bldg management style
- Demographics: age, health, circadian sensitivity, cirdacian exposure status

F Building Energy Systems

- Lighting: Installed Kwh, control zones, perfect dimming, complex switching, control logic, mutiple systems, fixture type and layout
- Heating: annual load, dynamic response
- Cooling: annual load, dynamic response
- Ventilation: annual load, dynamic response, variable windows

C-2.9 Energy Plus w Radiosity

White cells show the capabilities of Ecotech at the time of evalution in 2007. Grayed cells are clearly outside of its capabilities, while blue cells might be achieved with some additional programing.

Figure 50: Energy Plus with Radiosity Framework

1		2		A		B		C		D		E		F
Human Comfort	+	Energy Impacts	=	Space Description	+	Fenestration Description	+	Climate Inputs	+	Exterior Context	+	Occupant Behavior	+	Building Energy Systems

1 Human Comfort

- **Illuminance**: Sufficiency, Uniformity, Gradiants
- **Lumiance**: Contrast ratios, Uniformity, Glare, Gradiants
- **Thermal**: Radiant
- **Circadian**: Spectrum, Intensity, Timing, Duration, Relative context

2 Energy Impacts

- **Lighting energy**: Full load equiv, Annual Kwh, Peak KW
- **Cooling**: Additional load, Annual Kwh, Peak KW
- **Heating**: Additional load, Annual Kwh, Peak KW
- **Ventilation**: Additional load, Annual Kwh, Peak KW

A Space Description

- **Geometry**: boxes, complex orthangonals, furniture, overhangs, fins, mullions, rods, angles, curves
- **Orientation**: cardinal, precise, latitude
- **Visual Properties**: diffuse reflectance, specular reflectance, internal transparency
- **Thermal Properties**: U-value, capacitance
- **Sensor locations**: one or two, cont. floor plane, any horizontal plane, any vertical plane, any view direction, global assessement

B Fenestration Description

- **Windows**: size & location, VLT, diffuse glazing, multiple orientations, angular dependance, optically complex glazing, dynamic BTDF, variable VLT
- **Skylights**: size & location, VLT, geometry, photometrics, dynamic BTDF, variable VLT
- **Int. blinds, shades, etc**: VLT, direct v diffuse, operating schedule, multiple schedules, multiple triggers, photometrics (angle, shape), dynamic BTDF
- **Ext.blinds, awnings, etc**: VLT, direct v diffuse, angle, shape, operating schedule

C Climate Inputs

- **Sun**: Altitude, Azimuth, Hourly Intensity, Terrain adjustments
- **Sky**: Uniform distribution, Hourly intensity, Perez distribution, Partly cloudy, Fog/haze, Precipitation
- **Thermal**: CDD/HDD, hourly temps, relative humidity, radiant component, wind speed, adjust for mircoclimate

D Exterior Context

- **Ground**: diffuse reflectance, slope, multiple conditions, specular reflectance, seasonal variation, weather variation
- **Buildings**: horizon shape, opaque boxes, diffuse reflectance, specular reflectance, complex shapes, transparency
- **Vegetation**: shape & location, reflectance, transparency, seasonal variation
- **Other**: cars, other variable sources?

E Occupant Behavior

- **Task**: task type, furniture layouts, task location, view direction
- **Blinds operation**: solar trigger, response time, glare trigger, angle setting, auto override, privacy, security, maintenance
- **Lighting Choices**: overhead control choices, task light control, auto override, maintenance
- **Occupant schedules**: occupancy type, hourly schedules, comfort needs, window operation, bldg management style
- **Demographics**: age, health, circadian sensitivity, cirdacian exposure status

F Building Energy Systems

- **Lighting**: Installed Kwh, control zones, perfect dimming, complex switching, control logic, mutiple systems, fixture type and layout
- **Heating**: annual load, dynamic response
- **Cooling**: annual load, dynamic response
- **Ventilation**: annual load, dynamic response, variable windows

C-2.10 SPOT

White cells show the capabilities of SPOT at the time of evalution in 2007. Grayed cells are clearly outside of its capabilities, while blue cells might be achieved with some additional programing.

Figure 51: SPOT Framework

1 Human Comfort + 2 Energy Impacts = A Space Description + B Fenestration Description + C Climate Inputs + D Exterior Context + E Occupant Behavior + F Building Energy Systems

1 — Human Comfort

- Illuminance: Sufficiency, Uniformity, Gradiants
- Lumiance: Contrast ratios, Uniformity, Glare, Gradiants
- Thermal: Radiant
- Circadian: Spectrum, Intensity, Timing, Duration, Relative context

2 — Energy Impacts

- Lighting energy: Full load equiv, Annual Kwh, Peak KW
- Cooling: Additional load, Annual Kwh, Peak KW
- Heating: Additional load, Annual Kwh, Peak KW
- Ventilation: Additional load, Annual Kwh, Peak KW

A — Space Description

- Geometry: boxes, complex orthangonals, furniture, overhangs, fins, mullions, rods, angles, curves
- Orientation: cardinal, precise, latitude
- Visual Properties: diffuse reflectance, specular reflectance, internal transparency
- Thermal Properties: U-value, capacitance
- Sensor locations: one or two, cont. floor plane, any horizontal plane, any vertical plane, any view direction, global assessement

B — Fenestration Description

- Windows: size & location, VLT, diffuse glazing, multiple orientations, angular dependance, optically complex glazing, dynamic BTDF, variable VLT
- Skylights: size & location, VLT, geometry, photometrics, dynamic BTDF, variable VLT
- Int. blinds, shades, etc: VLT, direct v diffuse, operating schedule, multiple schedules, multiple triggers, photometrics (angle, shape), dynamic BTDF
- Ext.blinds, awnings, etc: VLT, direct v diffuse, angle, shape, operating schedule

C — Climate Inputs

- Sun: Altitude, Azimuth, Hourly Intensity, Terrain adjustments
- Sky: Uniform distribution, Hourly intensity, Perez distribution, Partly cloudy, Fog/haze, Precipitation
- Thermal: CDD/HDD, hourly temps, relative humidity, radiant component, wind speed, adjust for mircoclimate

D — Exterior Context

- Ground: diffuse reflectance, slope, multiple conditions, specular reflectance, seasonal variation, weather variation
- Buildings: horizon shape, opaque boxes, diffuse reflectance, specular reflectance, complex shapes, transparency
- Vegetation: shape & location, reflectance, transparency, seasonal variation
- Other: cars, other variable sources?

E — Occupant Behavior

- Task: task type, furniture layouts, task location, view direction
- Blinds operation: solar trigger, response time, glare trigger, angle setting, auto override, privacy, security, maintenance
- Lighting Choices: overhead control choices, task light control, auto override, maintenance
- Occupant schedules: occupancy type, hourly schedules, comfort needs, window operation, bldg management style
- Demographics: age, health, circadian sensitivity, cirdacian exposure status

F — Building Energy Systems

- Lighting: Installed Kwh, control zones, perfect dimming, complex switching, control logic, mutiple systems, fixture type and layout
- Heating: annual load, dynamic response
- Cooling: annual load, dynamic response
- Ventilation: annual load, dynamic response, variable windows

C-3 Levels of Analysis

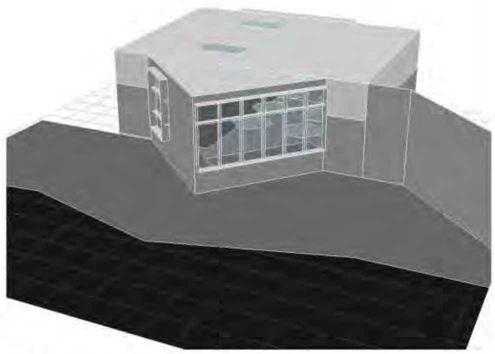
Level One is the simplest level of detail, appropriate for schematic design, to test the performance of alternative design strategies. This level of analysis would be appropriate to guide early design, allowing quick iterative runs, or to show compliance with daylight performance standards, such as LEED or CHPS or IGCC, for simple buildings. A requirement for quick and easy modeling suggests reduced granularity of geometric detail and analysis grids, and also implies that a variety of professional-grade tools would be available to generate the required metrics. This level would use default assumptions for most conditions that are not knowable during early design, and optimistic assumptions about user operation and reflectances, to define the upper limit of the “daylight potential” for the space. Window conditions would be defined with simplified two-dimensional openings, surface reflectance as standard defaults, and exterior conditions simplified to just a few inputs such as ground reflectance. The operation schedule should be set as a standard 10 hour day, 8am-6pm clock time, covering normal daylit operating hours and avoiding extreme dawn and dusk conditions. Furniture could be ignored, or modeled with only the largest likely objects considered, such as library stacks or cubical partitions.

Level Two would contain higher level of detail, as appropriate for demonstrating compliance with codes or standards at the completion of construction documents. Logically, for verification at this phase, the input details and assumptions should be verifiable from construction documents and an approved calculation methodology. For these purposes, Level Two should generally make pessimistic assumptions about interior furnishing and operating schedules to define a minimally acceptable condition that is likely to be maintained in spite of common insults to operational efficiency. This level should include material properties determined by the building specifications, or prescribed defaults where appropriate for code compliance. Window details should be three dimensional to include inter-reflections and shelf-shading from framing elements. Operating schedules, window treatments and obstructions should follow standardized rules to avoid gaming.

Level Three contains the highest level of simulation detail, appropriate for modeling existing buildings for research or verification purposes, where actual furniture layouts, window treatments, surface colors, operating schedules and exterior obstructions are known. This level includes measured data where available, such as surface reflectance and operating schedules, or level two defaults when not available. Exterior details should be fully modeled, including vegetation. The goal of level three is to include the finest resolution of relevant details, such that realistic comparison to occupant experience or monitored conditions is possible. Logically, for field verification, comparable results should be possible to derive from both simulation input and field data, such as monitored illuminance levels or photographic luminance capture techniques. Because analysis at this level is most interested in realistic models research-grade simulation tools that favor accuracy over ease-of-use simplifications would be most appropriate.

C-4 Daysim Report from Christoph

IRC Institute for Research in Construction



Project 4 Daylighting Metrics Project
Task 4.5 Simulation Study Methods

Consultant Report

Prepared For:
California Energy Commission
Public Interest Energy Research Program

July 31, 2008
500-06-502

CALIFORNIA ENERGY COMMISSION

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Executive Summary – Task 4.5 Simulation Studies

This is report summarizes the simulation work carried out by the National Research Council of Canada – Institute for Research in Construction (NRC-IRC) for the California Energy Commission's Public Interest Energy Research (PIER) Program, *Building End-Use Energy Efficiency and Renewable Energy Technologies - Research Development, and Demonstration Program for Energy-efficient Advanced Lighting* (RFP # 500-06-502). This work was done as a subcontract under 'Project 4 Daylighting Metrics' which is managed by the Heschong Mahone Group (HMG) in Fair Oaks, California. The goal of the Daylighting Metrics Project was to 'increase the use of daylighting in buildings that will save energy, reduce peak electricity demands, and improve occupant comfort and satisfaction in those buildings' (HMG proposal to CEC, 2006). Project objectives were to 'develop a set of daylight performance metrics and criteria ..., which can be used in programs, codes and standards to promote more daylit buildings, and thus greater energy savings and demand reduction' (HMG proposal to CEC, 2006).

The basic research approach used by the project team was to correlate field data and simulation results for sixty-one spaces located in California, the Pacific North West, and New York State. The work for this project was carried out by three project partners, HMG, the Integrated Design Laboratory in Seattle (IDL), and NRC-IRC. The work was initially split into four distinct steps, according to the responsibilities of each project partner: Collect survey data (lead HMG); prepare Ecotect models of the spaces (lead IDL); calculate the annual daylight availability in the spaces (lead NRC-IRC) and connect the simulation results with the subjective space evaluations (lead HMG). This report concentrates on the daylight modeling aspects of the project.

IDL initially built Ecotect modes of sixty-one spaces and exported all of them twice into the Radiance file format: Once in a very detailed fashion ('as built' models) and a second time in a less rigorous mode that corresponds more to the level of modeling detail that a design team would typically generate during schematic design ('space potential' models). For both types of models NRC-IRC generated annual illuminance profiles at key positions within the spaces using the Radiance-based Daysim program. Key positions in each space were located on a grid of upward facing illuminance sensors at work plane height (31 inches or 0.79 m above the floor) as well as on a grid of downward facing 'ceiling' sensors just inches below the lowest part of the ceiling.

In addition to the annual illuminance profiles so-called 'direct shading profiles' were generated that flag the appearance of direct sunlight over $50 Wm^{-2}$ at eyelevel height (48 inches or 1.22m above the floor) throughout a space at every hour of the year. The direct shading profiles can be used as triggers to decide when a dynamic shading device needs to be closed due to direct glare. For each space, up to four independent blind groups were modeled. A blind group corresponds to one or several movable shading devices that are operated synchronously throughout the year. E.g. a space that is bi-laterally through openings in the North and South façades would typically have two blind groups representing the shading devices in the North and South façade, respectively. Based on the direct shading profile, the blind groups can then be operated so that the appearance of direct glare at eyelevel within the space is minimized.

Finally, a 'sky view' and a 'direct sunlight penetration' file were generated for each space. Sky view files report for each eyelevel sensor the percentage of the celestial hemisphere that is 'seen' by each sensor. Direct sunlight penetration files report for each eyelevel sensor and each hour of the year whether the sensor is exposed to more than $50Wm^{-2}$ direct normal solar radiation.

All in all, 516 annual illuminance profiles were generated with each illuminance profile containing roughly five million simulated illuminances, the exact number depending on the number of work plane or ceiling grid points for each space. The resulting daylight simulation database combined with the expert and occupant surveys of the spaces constitutes a world-wide unique resource for daylighting research and daylighting incentive programs alike: It will allow us to finally determine scientifically-based benchmarks for climate-based daylighting metrics such daylight autonomy, useful daylight illuminance and others. These benchmarks will lead to better daylighting ratings for building codes, incentive programs and green building rating systems. For researchers working on 'new' daylighting metrics the data set could serve as an invaluable aid to verify the validity of their approach using real world data.

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1 Introduction

This report summarizes the simulation work carried out by the National Research Council of Canada – Institute for Research in Construction (NRC-IRC) for the California Energy Commission's Public Interest Energy Research (PIER) Program, *Building End-Use Energy Efficiency and Renewable Energy Technologies - Research Development, and Demonstration Program for Energy-efficient Advanced Lighting* (RFP # 500-06-502). This work was done as a subcontract under 'Project 4 Daylighting Metrics', which is managed by the Heschong Mahone Group (HMG) in Fair Oaks, California. The goal of the Daylighting Metrics Project was to 'increase the use of daylighting in buildings that will save energy, reduce peak electricity demands, and improve occupant comfort and satisfaction in those buildings' (HMG proposal to CEC, 2006). Project objectives were to 'develop a set of daylight performance metrics and criteria …, which can be used in programs, codes and standards to promote more daylit buildings, and thus greater energy savings and demand reduction' (HMG proposal to CEC, 2006).

Figure 1 summarizes the basic research approach used by the project team to correlate field data and simulation results for sixty-one spaces located in California, the Pacific North West, and New York State. The work for this project was carried out by three project partners, HMG, the Integrated Design Laboratory in Seattle (IDL), and NRC-IRC. The work was initially split into four distinct steps, according to the responsibilities of each project partner (Figure 1): Collect survey data (lead HMG); prepare Ecotect models of the spaces (lead IDL); calculate the annual daylight availability in the spaces (lead NRC-IRC) and connect the simulation results with the subjective space evaluations (lead HMG). This report concentrates on the daylight modeling aspects of the project lead by NRC-IRC (Task 4.5 'Simulation Studies').

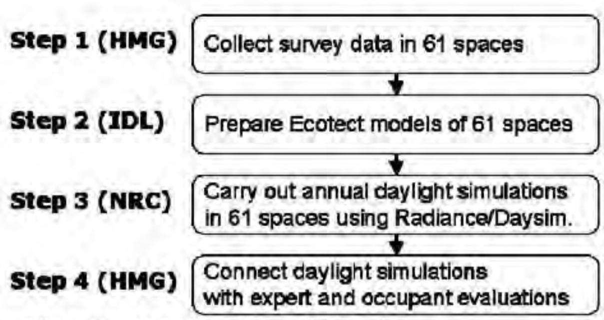


Figure 1: Overview of the basic research approach used in this study.

- Step 1: Collect survey data: According to their use and availability, sixty-one spaces were initially selected. Each space was assigned to be a classroom, an open office or a library-type space. The exact definitions of these space types as well as the selection criteria used to pick the individual spaces is documented elsewhere [**HMG report on surveys**]. The data collected for each space included detailed measurements of space geometries, optical properties of material surfaces, space usage patterns, and occupant surveys of how movable shading devices (venetian blinds, shades etc.) within the spaces were operated. The surveys were further complemented with expert and occupant evaluations of all spaces. Results from the surveys are documented under [**HMG report on** surveys]]. Section 2 briefly outlines the survey information that were used to build the daylighting models of the spaces.

- Step 2: Prepare Ecotect models: Early into the project the project team decided to generate two levels of models for all spaces: 'As built' models and 'space potential' models. As built models aim to model each space with as much detail and rigor as possible including information that is generally not be available during schematic design such as furniture layout and exact space usage patterns (occupancy and blind control). In contrast 'daylight potential' models represent what one might consider 'good simulation practice models' for the schematic design stage. A more comprehensive description of both model types is provided in Section 3.

  Ecotect version 5.6 was used to generate 3-dimensional representations of the sixty-one spaces (http://www.squ1.com/). Ecotect was chosen for this task for various reasons: The Ecotect GUI allows the user to efficiently model 3-dimensional spaces, assign material properties to individual surfaces and conveniently generate sensor point grids for further daylighting analysis. Most importantly, Ecotect can reliably export this information into the Radiance file format. A set of modeling instructions of how to prepare the Ecotect models and how to export the resulting data into Radiance was prepared by NRC-IRC for the other project partners. These instructions are summarized in Section 4 and Appendix A. Based on these instructions IDL built the Ecotect models of all sixty-one spaces.

- Step 3: Carry out annual daylight simulations: NRC-IRC imported the Radiance files generated in Step 2 into the Daysim program in order to generate annual illuminance and direct shading profiles of key positions within the spaces (www.daysim.com). An annual illuminance profile corresponds to an annual time series of (in this case) hourly mean illuminances at a point in a building. These profiles can be used to derive so-called 'climate-based daylighting metrics' that summarize the daylight situation within a space depending on local climate, space geometry, occupant requirements and the operation of any movable shading devices (Reinhart, Mardaljevic and Rogers 2006). A direct shading profile reports the hourly appearance of direct sunlight above $50 Wm^{-2}$ at selected sensor points in a building. This information can be used as a trigger to decide when the blinds need to be closed due to direct glare (Reinhart and Voss 2003) .

  Daysim is a Radiance-based advanced daylighting analysis tools that now uses the recently developed DDS daylight coefficient file format (Bourgeois, Reinhart and Ward 2008) combined with the Perez all weather sky model (Perez, Seals and Michalsky 1993) to predict the annual amount of daylight for each hour in the year based on direct and diffuse irradiances taken from a TMY file. Daysim has been rigorously validated using tens of thousands of interior illuminance measurements in full-scale sidelit test rooms which were equipped with a conventional clear double-glazing combined with an exterior venetian blind system in a variety of blind positions (Reinhart and Walkenhorst 2001). A more recent validation study included a full-scale sidelit space with a large translucent panel (Reinhart and Andersen 2006).

  A strong effort was further made in this study to accurately model the effect of venetian blinds and other movable shading devices on the overall daylight availability within the spaces. Details are provided in Section 4 of this document.

- Step 4: Connect simulations with subjective space evaluations: HMG will later take the lead in connecting the annual daylight simulation results from Step 3 with the expert and occupant evaluations of the spaces that were collected during Step 1.

Which simulation program to use?

A point of debate at the beginning of this project was which daylight simulation program to use. Three obvious choices were SPOT (Sensor Placement and Optimization Software; http://www.archenergy.com/SPOT/index.html), a Radiance-based simulation program that uses Excel as a graphical user interface for building a Radiance model and displaying simulation results, the split-flux method that is imbedded in eQuest/DOE2.1, and Daysim. In the end Daysim was chosen for the following reasons:

- Demonstrated accuracy: The above mentioned validation studies that Daysim has undergone currently set the program apart from any other dynamic daylight simulation program such as SPOT. SPOT currently uses a non-validated daylight-coefficient-type method base on selected representative sky conditions at various times of the year. According to a recent LEUKOS paper that was co-authored by the main developer of SPOT (Reinhart et al. 2006) the new release of SPOT will use the Daysim binaries for the calculation of the annual illuminance profiles. This makes SPOT a *de facto* Excel-based graphical User Interface for Daysim.

  The split flux method used in DOE2.1 was initially validated by Winkelman and Selkowitz (Winkelmann and Selkowitz 1985). The method is robust and widely used. But, – as already stated by the authors in their initial validation paper – the algorithm provides inherently less accurate results than Radiance at sensor points further away from a façade where the daylight has been internally reflected multiple times. A recent comparison of Daysim with DOE2.1 simulations showed that the latter tends to predict lower illuminances than Daysim in the back of a room (Koti and Addison 2007).
- Added flexibility: Another advantage of using the Daysim program within this project is that it runs under Windows and Linux environments and can be fully executed and integrated into Linux scripts. This fact allowed the project team to develop a database of Radiance/Daysim models of all sixty-one spaces. This database offers the advantage that new daylight simulation metrics and blind modeling approaches can easily be tested at a later point in time.
- Multiple blind groups: Within this project the capability of simulating multiple, independent blind groups was added to Daysim (see Section 4). This allows Daysim to open or close up to ten groups of shading devices independently in order to avoid direct glare while still admitting daylight from non-glaring directions into the space.

What are the consequences of using Daysim?

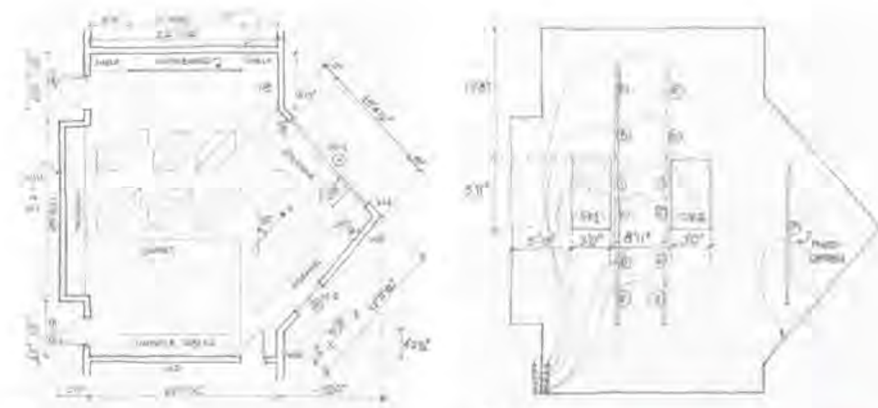
It is worthwhile mentioning that the selection of Daysim/Radiance as the daylight simulation tool for this study does not necessarily imply that Daysim will have to be the tool that is used by design teams who want to apply the results from this project. Instead it will be relatively straightforward for the developers of other daylighting design tools to implement the outcome of this work into their tool and the author expects that this is indeed going to happen. The main requirement for any tool to use the outcomes of this project is that it can generate annual illuminance profiles. The next step, extracting a climate-based daylight metric from an annual time series, tends to be a trivial modeling exercise. What is not trivial is to identify a suitable metric and to develop benchmarks for the metric. For example, the daylight factor metric really only became somewhat useful as a design metric when a minimum requirement of 2% was introduced. Similarly one needs a target level for climate-based metrics such as daylight autonomy and useful daylight illuminance. Given this background it was a key concern for the project team to develop climate-based metrics that lend themselves to be easily calculated as part of a smooth, somewhat automated simulation workflow.

2 Field Surveys

Field data in sixty-one spaces was collected during the summer and fall of 2007. A detailed description of the survey protocol is presented elsewhere [HMG report on surveys]. For the purpose of the daylight simulations the following measurements were performed in all spaces:

- Outside horizontal illuminance readings at the beginning and end of the field visits
- Photographs of the space and its surroundings
- A rough sketch of neighboring buildings and obstructions
- A detailed floor plan of the space and it boundaries (Figure 2 (a))
- An reflected floor plan showing electric lighting installations and position of skylights (if applicable) (Figure 2 (b))
- Window elevations, frame details, and facade sections
- Material properties of inside surfaces (reflectances), fenestrations (type or estimated visual transmittance), and shading devices (type and setting during the visit)

In order to better understand the occupancy schedule and usage pattern of the spaces, occupancy surveys were carried out as well.



(a) (b)

Figure 2: Example floor plan (a) and reflected floor plan (b) for a classroom [**HMG report on surveys**].

3 'Space potential' and 'As built' Models

The final goal of this project was to develop a calculation procedure and meaningful benchmarks for climate-based daylighting metrics that can be implemented into building codes and green building rating systems such a California's Title 24 (CEC 2008) and the USGBC's LEED system (USGBC 2006). In order to make progress towards this goal the 'daylighting' within the sixty-one investigated spaces was evaluated by space occupants and daylighting experts. These subjective evaluations will later be correlated to the daylight simulation results of these spaces. In order to identify any statistically significant correlations between the simulations and the user assessments the daylight simulations had to be as detailed and rigorous as possible. This required the modeling of any furniture, mimicking space usage, window details, the existence of movable shading devices and actual surface reflectances. Since such modeling detail is usually neither available nor can it realistically be attained during schematic design, a second type of model was also proposed that corresponds more to what one might typically expect from a daylighting model at that stage. These somewhat simplified, abstract models were termed 'space potential' or 'level I' models. The detailed models were called 'as built' or 'level III'. The terms simple, space potential and level I as well as detailed, as built and level III will be used somewhat interchangeably throughout this report. Table 1 lists the differences between the two model types. The two different types of models will allow the project team to establish how robust the resulting daylighting metrics benchmarks are with respect to modeling detail.

Table1: Overview of two model types, 'Space potential' (level I) and 'As built' (level III) models.

	'Space potential' (level I)	**'As built' (level III)**
Design phase	Schematic	As built (and commissioned)
Purpose	For participation in voluntary standards, competitions, initial design reviews.	For as operated conditions, research level analysis, post occupancy evaluation, benchmarking.
External obstructions	Neighboring structures and landscape including vegetation up to a distance equal to the distance between the height of window head and the external ground. Default reflectances of 40% for all exterior surfaces	Same as 'space potential'.
Interior surfaces	Assuming standard 20%, 50% and 80% for all interior floors, walls and ceilings.	As furnished, including partitions and large furniture with a minimum dimension of 4 inches (10cm). Reflectances of all surfaces were modeled in 10% bins (0%, 10% ... 90%).
Windows	Net window area assuming a generic frame that takes up 20% of the rough window opening. Exterior walls were modeled in 2 dimensions (infinitely thin). Clear and translucent glazings were modeled as built with transmittances set in 5% bins.	Exact model of the window frame and of mullions larger than 4 inches (10cm). Overall modeling resolution of 2' (5cm). Thickness of exterior walls taken into account. Clear and translucent glazings were modeled as built with transmittances set in 5% bins.
Movable shading	Movable shading devices were modeled as up to four blind groups that can be operated independently. Blind operation was modeled as either fixed in a particular position or automatically operated for optimized view, glare, and thermal comfort.	Movable shading devices were modeled as furnished with up to four blind groups that can be operated independently. Blind operation was modeled as close to actual usage as possible based on best case conditions or self-reported operation.

4 Modeling Instructions for Ecotect

This section summarizes the modeling instructions that NRC-IRC provided to IDL and other project team members who were involved in building the Ecotect models of the sixty-one spaces.

4.1 Initial 'Training'

IDL was advised to initially consult the 'Getting Started with Ecotect/Radiance/Daysim' document in order to learn how to build a model in Ecotect and export it into Radiance/Daysim. The document is available from the Daysim web site (www.daysim.com).

4.2 Model Settings

Before modeling a space the modelers were reminded to carefully set the proper building location, orientation, and architectural units for the model. For each site the closest available TMY file was selected from the US Department of Energy's EnergyPlus weather data site (http://www.eere.energy.gov/buildings/energyplus/cfm/weather_data.cfm). The EPW files can be directly converted into Daysim for an annual daylight simulation.

4.3 Material Names

In order to streamline the modeling of the sixty-one spaces, and to ensure consistency across the models, all materials in the Ecotect/Radiance/Daysim scenes had to follow the same naming convention. For this purpose an Ecotect material library was custom-made for this project. This library was used as the default library for each space and all materials within the models were assigned a material name from this library. Table 2 lists all materials available within the library. Based on the survey measurements (Section 2) each surface in the models could unambiguously be assigned a material name from the Ecotect library. Section 5 describes how the different materials were later modeled in Radiance/Daysim.

4.3.1 Opaque Surfaces

All opaque surfaces were assumed to be Lambertian (diffuse reflectors) and reflectances were set in 10% bins based on the survey measurements. E.g. for a measured wall reflectance of 63% the material name for this wall would be 'SpecificWall_60' (see Table 2).

How to estimate diffuse surface reflectances?

During the surveys illuminance and luminance measurements were taken of all major surfaces within a space. Based on this information the diffuse reflectance of these surfaces could be estimated. For example, assuming that the survey yielded an illuminance of 3.07 foot-candles on a whiteboard and 7.9 candela/m^2 off the board, the estimate diffuse reflectance of the whiteboard would be:

$$\rho_{diffuse} = \frac{L \cdot \pi}{E}$$

with $\rho_{diffuse}$ = diffuse reflectance
L = luminance in candela per m2
E= illuminance in lux (with 1 foot candle = 10.76 lux)

$$\rho_{diffuse} = \frac{7.9 \cdot \pi}{3.07 \cdot 10.76} = 75\% \sim 70\%$$

The resulting material name for the furniture surface would be 'SpecificFurniture_70'.

4.3.2 Clear Glazings and Shading Devices

For all glazings the direct normal visual transmittance of the glazing unit from the survey was estimated to the closest 5% bin. In addition the surveyors noted whether a window was equipped with a movable shading device such as venetian blinds or drapes. E.g. a glazing unit with a direct normal visual transmittance of 55% and a venetian blind would be called 'ClearGlazing_55_Shading.

In the presence of multiple movable shading devices within a space, the surveyors had the option of organizing the shading devices into 'blind groups'. The assumption during the simulation was that all shading devices within a blind group are opened and closed synchronously over the year. In order to assign a window to a blind group other than the first blind group of the space the material name of the glazing unit would get another suffix, '_GR2', '_GR3', ... '_GRn'. The maximum number of blind groups in any space was four. Appendix B lists the number of blind groups for each space.

4.3.3 Translucent Glazings

All translucent glazings were assumed to be perfect diffusers. The direct normal hemispherical transmittance of the each panel was estimated in 5% bins resulting in material names such as a 'Translucent_45' (Table 2). Translucent glazings were not equipped with movable shading devices in any of the spaces.

Table2: List of material names in the Ecotect material library that was used for all sixty-one spaces.

Surface Type	Material name	Material Property
Walls	GenericWallForLighting	50% diffuse reflectance
	SpecificWall_10	10% diffuse reflectance
	SpecificWall_20	20% diffuse reflectance
	...	...
	SpecificWall_90	90% diffuse reflectance
Floors	GenericFloorForLighting	30% diffuse reflectance
	SpecificFloor_10	10% diffuse reflectance
	SpecificFloor_20	20% diffuse reflectance
	...	...
	SpecificFloor_90	90% diffuse reflectance
Ceiling	GenericCeilingForLighting	80% diffuse reflectance
	SpecificCeiling_10	10% diffuse reflectance
	SpecificCeiling_20	20% diffuse reflectance
	...	...
	SpecificCeiling_80	80% diffuse reflectance
Furniture	GenericFurniture	50% diffuse reflectance
	SpecificFurniture_10	10% diffuse reflectance
	SpecificFurniture_20	20% diffuse reflectance
	...	...
	SpecificFurniture_80	80% diffuse reflectance
Specialty Materials	Airwall	0% reflectance[1]
	Trees	40% diffuse reflectance
Clear Glazings	ClearGlazing_05_NoShading	clear glazing with a 5% direct normal transmittance and no shading device
	ClearGlazing_15_NoShading	same as above with a 15% direct normal transmittance
	...	...
	ClearGlazing_95_NoShading	same as above with a 95% direct normal transmittance
	ClearGlazing_05_Shading	clear glazing with a 5% direct normal transmittance and a shading device in blind group 1
	ClearGlazing_15_Shading	same as above with a 15% direct normal transmittance
	...	...
	ClearGlazing_95_Shading	same as above with a 95% direct normal transmittance
	ClearGlazing_05_Shading_GR2	clear glazing with a 5% direct normal transmittance and a shading device in blind group 2
	...	...
	ClearGlazing_95_Shading_GR2	same as above with a 95% direct normal transmittance
	ClearGlazing_05_Shading_GR3	clear glazing with a 5% direct normal transmittance and a shading device in blind group 3
	...	
	ClearGlazing_95_Shading_GR4	clear glazing with a 5% direct normal transmittance and a shading device in blind group 4
Translucent Glazings	GenericTranslucent20	diffusing material with a direct normal hemispherical transmittance of 20%
	Translucent_25	diffusing material with a direct normal hemispherical transmittance of 25%
	...	...
	Translucent_75	diffusing material with a direct normal hemispherical transmittance of 75%

[1] 'Airwall' was the material used to model internal boundaries of an investigated space and the remainder of the building in which the space was located. See also Section 4.4.2.

4.4 Space Geometry

The geometry of each space was modeled as closely as possible to reality including any larger pieces of furniture (desks and partitions), external wall thicknesses, window frames and mullions with a width greater than 2 inches (5cm). Further attention was paid to structural elements near windows and skylights that strongly influence the daylight within a space. In order to be able to export 'space potential' (level I) and 'as built' (level III) models to Radiance/Daysim from the same Ecotect file, mullions, glazings, furniture, wall thicknesses, and external obstructions all had to be placed on separate Ecotect zones. A zone in Ecotect corresponds to what would be called a 'layer' in many other CAD programs. A zone can be turned on or off during export.

4.4.1 External Obstructions

As a rule of thumb external obstructions such as neighboring buildings and landscape were modeled up to a distance of the window-head-height in a space to the outside ground (see example in Figure 3)

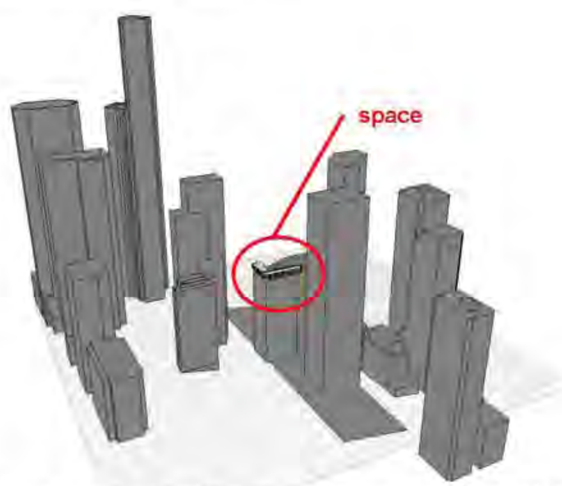


Figure 3: External obstructions were modeled to a distance of the window-head-height to the outside ground.

4.4.2 Space Boundaries

In smaller spaces the boundaries of the space simply coincided with the walls but in larger spaces such as libraries the investigated 'daylit' space consisted of a portion of the overall space. The boundaries of that portion were usually set along logical boundaries of different usage patterns within the larger space, e.g. a sitting/reading area as opposed to the book stacks or reception area within a library. In case the remainder of a building outside of the study space was too complex to be modeled, an 'air wall' was introduced between the study space and the remainder of the building. Air walls were modeled as opaque elements with zero reflectance.

4.5 Sensor Points

In each space three grids of sensors were defined. These sensor grids were then exported to Radiance/Daysim for further analysis.

- Work plane sensors: Work plane sensor grids consist of a horizontal grid of upward facing illuminance sensors. The grid lies 31 inches (0.79 m) above the floor, has a 1 ft x 1 ft (0.3 m x 0.3 m) resolution and extends across the whole study space with an outside margin of about 1 ft (0.3 m).
- Ceiling sensors: Ceiling sensor grids consist of a horizontal grid of downward facing illuminance sensors. The grid lies about 1 inch (0.025 m) below the lowest ceiling height, has a 1 ft x 1 ft (0.3 m x 0.3 m) resolution and extends across the whole study space with an outside margin of 1 ft (0.3 m).
- Eyelevel sensors: Eyelevel sensor grids consist of a horizontal grid of upward facing illuminance sensors. The grid lies 48 inches (1.22 m) above the floor, has a 1 ft x 1 ft (0.3 m x 0.3 m) resolution and extends across the whole study space with an outside margin of about 1 ft (0.3 m).

4.6 Export to Radiance/Daysim

The Ecotect models were exported as level I and level III models into Radiance/Daysim using the file naming convention described in Appendix A. For the detailed (level III) models all geometric detail was turned on whereas for the simplified models the zones including the mullions and furniture were turned off during export. Only scene geometry and sensor information were exported to Radiance/Daysim (see Figure 5). The materials were modeled in Daysim as described in Section 5.

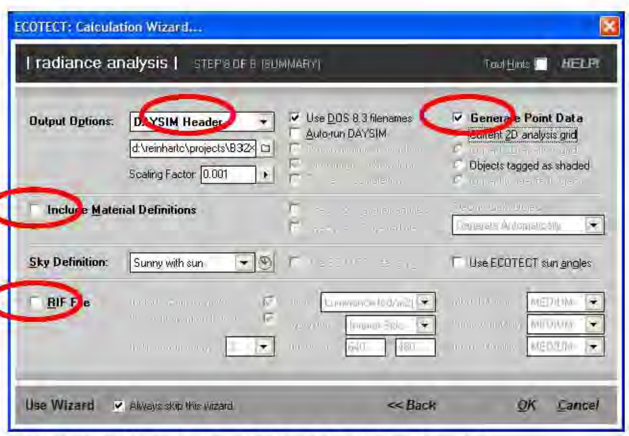


Figure 4: Ecotect to Radiance/Daysim export for detailed and simple models.

5 Radiance/Daysim Simulations

This section reports how the sixty-one spaces were modeled in Radiance/Daysim.

5.1 Material Descriptors

As explained above, all surfaces were assigned material names according to the naming convention from Table 2. Within Daysim two material libraries were used for the 'space potential' (level I) and 'as built' models (level III).

- Opaque surfaces: In detailed mode opaque surfaces were modeled as Lambertian surfaces according to their measured reflectance. E.g. for a 50% wall (SpecificWall_50) the Radiance/Daysim material was (Ward and Shakespeare 1998):

```
void plastic SpecificWall_50
0      0
5      0.5   0.5   0.5   0     0
```

  For the simplified mode all ceilings, walls and floors were assigned diffuse reflectances of 80%,50% and 30%, respectively.

- Clear glazings: In detailed mode clear glazings were modeled as typical double glazings using the 'glass' modifier in Radiance (Ward and Shakespeare 1998). E.g. a glazing with a direct normal transmittance of 70% and no movable shading device was modeled as:

```
void glass ClearGlazing_70_NoShading
0 0
3 0.763 0.763 0.763
```

  Note that a transmissivity value of 0.763 corresponds to a direct normal transmittance of 70%. For the simple mode the effect of window frames and mullions was approximated using a frame factor of 20%, i.e. the resulting Radiance material descriptor from the example glazing above for the simple mode was:

```
void glass ClearGlazing_70_NoShading
0 0 3 0.610 0.610 0.610
```

  with 0.610 = 0.8 x 0.763.

- Translucent glazings: In detailed mode translucent glazings were ideal diffusers using the 'transdata' material modifier (Ward and Shakespeare 1998). E.g. for a translucent glazing with a direct normal hemispherical transmittance of 20% the Radiance material was (Reinhart and Andersen 2006):

```
void transdata GenericTranslucent20
4 noop GenericTranslucent20.dat rang.cal rang
0
6 0.40446 0.40446 0.40446 0.08 0.435635 1
```

For the simple mode the effect of the window frame and mullions was again summarized through a frame factor of 20%.

5.2 Movable Shading Devices

How to efficiently model movable shading devices such as venetian blinds is an area of ongoing research (Laouadi, Reinhart and Bourgeois 2008). It is, in principle, possible to simulate an explicit, geometric blind model in Radiance/Daysim (Reinhart and Walkenhorst 2001). But, this brute force approach has its limitations since (a) the time required to accurately model individual venetian blinds is prohibitively time consuming, (b) actual venetian blinds found in the field are usually not properly aligned, or dusted, and are otherwise different from the manufacturer's ideal, and (c) the time to actually run a simulation typically extends from hours to days. A previously used alternative to the brute force approach is to simply assume that drawn venetian blinds with a slat angle of about 45° facing outwards approximately block all direct sunlight and transmit 25% of all diffuse daylight (Vartiainen 2001). This simplified approach has been used by Daysim version 2.1 and older. Its distinct advantage is that instead of having to calculate two sets of daylight coefficients (one for all movable shading devices open and another for all shading devices closed) only a single set has to be calculated with all shading devices open. The second set can be approximated by setting all direct daylight coefficients to zero and reducing the diffuse daylighting coefficients by 75%. This technique is a 'quick and dirty' approach for estimating the effect of movable shading devices on a space in which all windows are equipped with blinds and in which all blinds are opened and closed simultaneously.

The approach has its clear limitation in spaces with windows in multiple facades and/or with skylights. A lot of the investigated spaces in this study fall under this category. Daysim was therefore expanded in order to accommodate multiple (up to ten) shading device groups, which can be opened and closed independently of each other. This added functionality required two improvements:

5.2.1 A New Simplified Blind Model

While the above simplified blind model works very efficiently if all external façade openings are equipped with venetian blinds, simply scaling the daylight coefficients does not work if only a few windows in a building model feature movable shading devices. One way of simulating such a situation without going all the way to the explicit venetian blind model is to model the combination of a glazing with a drawn venetian blind as an ideal diffuser with a transmittance for diffuse daylight that corresponds to that of the glazing reduced by 75% and a transmittance for direct daylight of zero. This material can be built in Radiance using the 'transdata' material modifier. E.g. for a clear glazing with a 75% direct normal transmittance the resulting Radiance material descriptor when the blinds are down corresponds to:

```
void transdata ClearGlazing_75_Shading
4 noop GenericZero.dat rang.cal rang
0
60.19285    0.19285    0.19285    0.081 0.94358    1
```

Where `GenericZero.dat` is:

```
# all direct contributions set to zero
##### HEADER #####
# one-dimensional data array
1
# irregularly spaced axis:
# two zeros - number of divisions - division values
0 0 2
0 90
##### Body #####
# Data values (direct transmittances all set to zero):
0.0000
0.0000
```

The decisive advantage of this approach is that the simulations for any of the shading devices lowered takes approximately the same time as with all shading devices opened.

5.2.2 Combining Multiple Blind Groups

Once the shading devices themselves can be sufficiently accurately modeled, the remaining task is to find an effective way to calculate all possible combinations of shading devices opened and closed. This problem has been solved as follows:

- Step 1 – Calculate daylight coefficient sets: For a space with 'n' independent blind groups 'n+1' daylight coefficient sets are calculated. The first set corresponds to the space with all movable shading devices opened. The other n daylight coefficient sets correspond to the space with one blind group closed at a time.
- Step 2 – Combine daylight coefficient sets: Once the 'n+1' daylight coefficient sets are available, one can calculate the illuminance at a sensor point at particular point in time for any shading device setting using the following formula:

$$E_{total} = E(all\ up) + \sum_{i=1}^{n} status(Blind\ i) \times \left(E(Blind\ i\ down) - E(all\ up)\right) \quad \text{(Equ.3)}$$

$$with\ status(Blind\ i) = \begin{cases} 0\ if\ blinds\ are\ up \\ 1\ if\ blinds\ are\ down \end{cases}$$

5.3 Simulation Parameters

To be consistent the same set of Radiance simulation parameters was used for all simulations. Since all spaces were standard sidelit and/or toplit space spaces a 'scene complexity' level of one could be assigned to all of them (see Daysim Tutorial section 2.1.4 (www.daysim.com) and Rendering with Radiance Chapter 6 (Ward and Shakespeare 1998)). Since for the blinds down option a 'transdata' material model was used instead of a standard glazing, the ambient bounce parameter was increased by one unit to 6.

As shown in Appendix B the maximum scene dimension of any of the models is 560 m. This large number was caused by the necessity to model neighboring buildings in urban Manhattan. Assuming a minimum model detail of about 2 inches ~ 5cm leads to the following requirement:

$$\frac{\max imumscene \dim ension \ x \ ambient \ accuracy}{ambient \ resolution} < 5cm \qquad \text{(Equ. 1)}$$

Leading to:

$$\frac{ambient \ accuracy}{ambient \ resolution} < \frac{0.05m}{560m} = 0.000089 \qquad \text{(Equ. 2)}$$

For this simulation a combination of aa = 0.05 and ar = 560 was chosen leading to the Radiance simulation parameters shown in Table 3.

Table 3: Utilized Radiance simulation parameters.

ambient bounces	ambient division	ambient sampling	ambient accuracy	ambient resolution	direct threshold
6	1000	20	0.05	560	0

5.4 Simulation Output

Using the above-described modeling assumptions the following simulation outputs were generated. The naming convention for all output files is given in Appendix A.

5.4.1 Annual Illuminance Profiles

For each space a full set of hourly annual illuminance profiles was calculated using the DDS daylight coefficient method (Bourgeois et al. 2008). A full set consisted of annual illuminance profiles for the work plane and ceiling sensor grids (Section 4.5) for the 'as built' and 'space potential' models. Depending on the number of independent blinds groups available within a model, the number of resulting annual illuminance profiles was 2 blind settings x 2 model modes x 2 sensor grids = 8 for a single blind group up to 5 blind settings x 2 model modes x 2 sensor grids = 20 for four blind groups. The file format for each annual illuminance profile is as follows:

```
1 1 0.500 0 0 ... 0
1 1 1.500 0 0 ... 0
1 1 2.500 0 0 ... 0
1 1 3.500 0 0 ... 0
1 1 4.500 0 0 ... 0
1 1 5.500 0 0 ... 0
```

```
1 1 6.500 0 0 ... 0
1 1 7.500 17 19 ... 19
1 1 8.500 72 82 ... 81
1 1 9.500 154 175 ... 174
1 1 10.500 200 229 ... 229
1 1 11.500 276 339 ... 334
...
```

Figure 5: File format of the annual illuminance profiles.

In each line the first three numbers correspond to the month, day, and time of day followed by n illuminances. The order and pertaining position and orientation for each sensor corresponds to the order of sensors in the sensor point files (*.pts) from Appendix A.

5.4.2 Direct Shading Profiles

Research on how to model manual blind operation of movable shading devices is still in its infancy and what we know is based on a very limited number of field studies, some of which are summarized in (Reinhart and Voss 2003). One finding from these field studies is that blinds are manually operated in a conscious and consistent way (as opposed to a random fashion) and that the closing of blinds in private offices can be relatively reliably triggered by the appearance of more than 50 Wm^{-2} of direct sunlight near a work space (Inoue, Kawase, Ibamoto, Takakusa and Matsuo 1988; Reinhart and Voss 2003). These findings led to the development of the Lightswitch-2002 'occupant behavior model' which closes the blinds for the day when direct sunlight above $50Wm^{-2}$ (direct normal component) hits a work plane sensor in a building (Reinhart 2004). The model reopens the blinds once a day in the morning upon arrival of the occupant(s) at their work places.

The $50Wm^{-2}$ criteria used by Lightswitch-2002 forms the basis for the direct shading profiles. The profiles typically check whether any of the work plane sensors in a space is hit by direct sunlight at a given time interval. This result is reported for all blind groups open as well as all possible combinations of one or two blind groups closed. Since the majority of project team members felt that it was too difficult to separate typical work plane sensors from all grid point sensors the Lightswitch direct glare criteria was relaxed in this project allowing up to 2% of all eyelevel sensors within a space to be subject to direct sunlight without assuming glare. The justification for this change is the assumption that some direct sunlight sufficiently far away from a work place sensor might actually be viewed as something positive by the occupants. This modification is not based on any documented field data evidence.

Another change was the use of 'eyelevel' sensors (1.22m above the floor) as reference positions for the direct glare instead of work plane sensors (0.79m above the floor) which have been used in the past. The motivation for this change was that the eyelevel seems to be a more appropriate location to check for direct sunlight than the work plane height.

An example of a direct shading profile for two blind groups is shown in Figure 6. The first three numbers correspond to the month, day and hour of the day. The fourth and fifth column correspond to the mean direct normal and diffuse horizontal irradiances for the given hour. The following four columns correspond to the direct shading status for all blind groups open, blind group one closed only, blind group two closed only, and both blind groups closed. E.g. at 8.30 AM the building itself blocks the direct sunlight which is already above the $50Wm^{-2}$ level. At 9.30 AM there is direct sunlight incident at more than 2% of all eyelevel grids when all blinds are open. But, closing blind groups 1 takes care of the direct glare problem. Similarly, at 11.30 AM closing blind group 2 gets rid of the direct glare. At 10.30 AM both blind groups have to be closed to avoid direct glare.

```
1 1 0.500 0 0 0 0 0 0
1 1 1.500 0 0 0 0 0 0
1 1 2.500 0 0 0 0 0 0
1 1 3.500 0 0 0 0 0 0
1 1 4.500 0 0 0 0 0 0
1 1 5.500 0 0 0 0 0 0
1 1 6.500 0 0 0 0 0 0
1 1 7.500 0 19 0 0 0 0
1 1 8.500 100 49 0 0 0 0
1 1 9.500 478 93 1 0 1 0
1 1 10.500 713 79 1 1 1 0
1 1 11.500 644 94 1 1 0 0
...
```

Figure 6: File format of the direct shading profiles.

The file format for three and four blind groups is as follows:

3 blind groups:

- Col 1-5: month, day, hour, direct normal irradiance, diffuse horizontal irradiance
- Col 6: direct shading status for all blind groups open
- Col 7 shading status for only blind group 1 closed
- Col 8 shading status for only blind group 2 closed
- Col 9 shading status for only blind group 3 closed
- Col 10 shading status for blind groups 1 and 2 closed
- Col 11 shading status for blind groups 1 and 3 closed
- Col 12 shading status for blind groups 2 and 3 closed

4 blind groups:

- Col 1-5: month, day, hour, direct normal irradiance, diffuse horizontal irradiance
- Col 6: direct shading status for all blind groups open
- Col 7 shading status for only blind group 1 closed
- Col 8 shading status for only blind group 2 closed
- Col 9 shading status for only blind group 3 closed
- Col 10 shading status for only blind group 4 closed
- Col 10 shading status for blind groups 1 and 2 closed
- Col 11 shading status for blind groups 1 and 3 closed
- Col 12 shading status for blind groups 1 and 4 closed
- Col 13 shading status for blind groups 2 and 3 closed
- Col 14 shading status for blind groups 2 and 4 closed

- Col 15 shading status for blind groups 3 and 4 closed

What are the limitations of the direct shading profiles?

Following a number of discussions within the project team it was decided to go with the above-described approach of lowering only one or two shading devices at a time to evaluate the appearance of direct glare near a work space. This procedure works sufficiently well for orthogonal spaces but it is acknowledged that this model is not fully general for more complex shapes and spaces in which more than two blind groups might have to be deployed in order to control direct glare. The author aims to develop a more general model in the future but - given the remaining time and resources available within the project - the team members agreed to work with this intermediate solution, which is completely appropriate for the overwhelming majority of study spaces.

5.4.3 Sky View Files

In order to quantify the amount of the celestial hemisphere seen by each sensor a new type of Daysim output called 'sky view file' was generated. A sky view file lists for each sensor in a sensor input file (*.pts) the percentage of the celestial hemisphere that is 'seen' by the sensor. For more a detailed analysis the percentage is reported individually for six altitude bands (0°-16°, 17°-32°, 33°-47°, 48°-63°, 64°-79°, 80°-90°) as well as for the whole hemisphere. An altitude of 90 ° corresponds to zenith.

An example of a sky view file is shown in Figure 7. Following five rows of header information each additional row refers to one eyelevel sensor (Section 4.5). The first three numbers in each row correspond to the position of the sensor within the Radiance/Daysim scene. The following six numbers correspond to the percentage of the overall hemisphere that the sensor sees within the six altitude bands. The last number in each row corresponds to the overall percentage of sky seen by the sensor, i.e. it is the sum of the six preceding numbers. The first example sensor in Figure 7 corresponds to an unobstructed outside sensor. The second sensor is located just outside of a vertical wall, i.e. it sees 50% of the sky dome.

```
# This file was generated by Daysim 3.0 or higher.
# It provides for each work plane sensor a percentage of how much
celestial hemisphere the sensor sees.
# A value of '100' indicates that the sensor is completely
unobstructed. A value of '0' corresponds to fully obstructed.
# Individual values are given for the full hemisphere (0-90) as
well as six altitude bands.
#x   y    z    0-16 17-32 33-47 48-63 64-79 80-90 0-90    ...
-3.8 1.7  3.4  26   24    21    17    9     3     100
-3.8 2.0  3.4  13   12    11    8     4     2     50
...
```

Figure 7: Format of the sky view files.

5.4.4 Direct Sunlight penetration Files

Direct sunlight penetration files report for each eyelevel sensor and each hour of the year whether the sensor is exposed to more than $50Wm^{-2}$ direct normal solar radiation assuming that all shading device groups are opened. An example of a direct sunlight penetration file is shown in Figure 8. The first three numbers correspond to the month, day and hour of the day. The fourth and fifth column correspond to the mean direct normal and diffuse horizontal irradiances for the given hour. The following 'n' columns correspond to the direct shading status for all blind groups open for each of the 'n' eyelevel sensor. The order of the sensors in each row corresponds to the sensors in the *eyelevel.pts files (see Appendix A). In the example file in Figure 8 the direct normal solar radiation first temporarily climbs above $50Wm^{-2}$ at 8.30 AM. At that point all three eyelevel sensor are exposed to the direct sunlight (1 = sensor exposes; 0 = sensor shaded). As the day progresses various sensor are exposed while others are shaded.

```
1 1 1 0.500 0 0 0
1 1 1 1.500 0 0 0
1 1 1 2.500 0 0 0
1 1 1 3.500 0 0 0
1 1 1 4.500 0 0 0
1 1 1 5.500 0 0 0
1 1 1 6.500 0 0 0
1 1 8.500 335 23 1 1 1
1 1 9.500 28 325 0 0 0
1 1 10.500 737 27 0 0 1
1 1 11.500 781 32 0 1 0
...
```

Figure 8: Format of the direct sunlight penetration files.

6 Summary and Outlook

This report provides a detailed account of NRC-IRC's daylight simulation activities that were carried out within the PIER Daylighting Metrics Project. A number of new simulation techniques were developed through this process. i. e. the Daysim program has been expanded to effectively calculate up to ten independently operated blind groups per space and a simple Radiance model for a clear glazing combined with a simple venetian blind has been developed using the 'transdata' Radiance material modifier. These innovations will be reported in more detail elsewhere.

Apart from these improvements one could argue that the simulations of the sixty-one spaces individually are not 'strikingly new'. What makes this data set exciting are (a) the sheer number and diversity of spaces and (b) that these are real spaces. Even more important is that detailed occupant and expert assessments of the daylight within these spaces are available. These user assessments will help us within this project to identify scientifically-based benchmarks for some emerging climate based daylighting metrics such as daylight autonomy, useful daylight illuminance and others. These benchmarks will in turn lead to better daylighting ratings for building codes, incentive programs and green building rating systems. For researchers working on 'new' daylighting metrics this unique data set could become an invaluable tool to verify the validity of their ideas using real world data.

Acknowledgement

This report is the result of numerous discussions between the various members of the Daylighting Metrics Project team. The author would like to particularly single out Lisa Heschong and Mudit Saxena from the Heschong Mahone Group who articulately pushed for the improvements to the Daysim blind model that were realized through this project as well as Chris Meek and Maximilian Foley from the Integrated Design Lab in Seattle who built all sixty-one Ecotect models. I further extend my thanks to Marilyne Andersen (Massachusetts Institute of Technology) and Kevin Van Den Wymelenberg (University of Idaho) for their invaluable comments and suggestions during our project meetings.

Appendix A: File naming convention

The general philosophy is that for each space the same naming convention is used. That way the simulation analysis can be largely automated and a larger set daylighting metrics can be analyzed. Each file name in a directory will have the same root name, which corresponds to the name of the directory (nyc01.sp1). The following files are required for each space:

A.1 Output from Ecotect Models

/<root>./<root>.eco: Ecotect file from which the simple and detailed Radiance models as well as the eQuest model can be exported.

/<root>./<root>.detailed.rad: Radiance scene file with the advanced space description. This file includes all space-specific Radiance material descriptors, mullions, and furniture data.

/<root>./<root>.simple.rad: Radiance scene file with the simplified space description. This file will not include any Radiance material descriptors, mullions, or furniture data.

/<root>./<root>.workplane.pts: Radiance sensor file that contains a grid of upwards facing work plane illuminance sensors (31 inches (0.7874 m) above the floor, grid resolution ~ 1ft x 1ft).

/<root>./<root>.eyelevel.pts: Radiance sensor file that contains a grid of upwards facing work plane illuminance sensors (48 inches (1.2192m) above the floor, grid resolution ~ 1ft x 1ft).

/<root>./<root>.ceiling.pts: Radiance sensor file that contains a grid of downwards facing illuminance sensors located just below the ceiling (1 inches below the ceiling , grid resolution ~ 1ft x 1ft).

/Models/<root>.epw: ASCII file of the EnergyPlus weather data for the space for the annual daylight simulations.

A.2 Output from Daysim Analysis

/<root>./<root>.<mode>.<sensor grid>.<blind status>.ill: Daysim annual illuminance profile where <mode> = 'simple' or 'detailed' (according to model mode I and III, respectively), <sensor grid> = 'workplane' or 'ceiling' depending on the underlying sensor grid, and, <blind status> = 'BaseGeometry', 'BlindGroup1", 'BlindGroup2", 'BlindGroup3" or 'BlindGroup4".

/<root>./<root>.<mode>.<sensor grid>.<blind status>.ds: Daysim daylight coefficients in DDS format where <mode> = 'simple' or 'detailed' (according to model mode I and III, respectively), <sensor grid> = 'workplane' or 'ceiling' depending on the underlying sensor grid, and, <blind status> = 'BaseGeometry', 'BlindGroup1", 'BlindGroup2", 'BlindGroup3" or 'BlindGroup4".

/<root>./<root>. <mode>.dir: Daysim direct shading profile where <mode> = 'simple' or 'detailed' (according to model mode I and III, respectively).

/<root>./<root>. <mode>.percentage_of_visible_sky.dat: Daysim sky view file where <mode> = 'simple' or 'detailed' (according to model mode I and III, respectively).

/<root>./<root>. <mode>.glare: Daysim direct sunlight penetration file where <mode> = 'simple' or 'detailed' (according to model mode I and III, respectively).

Appendix B: Model Overview

Location	Building	Space Number	# of Blind Groups	Maximum Scene Dimension [m]
New York City	nyc01	1	1	25.60322
New York City	nyc01	2	2	66.16394
New York City	nyc02	1	2	31.69922
New York City	nyc02	2	2	31.69922
New York City	nyc04	1	3	565.9021
New York City	nyc04	2	2	565.9021
New York City	nyc05	1	3	484.4796
New York City	nyc05	2	1	484.4796
New York City	nyc08	1	1	77.10966
New York City	nyc08	2	1	77.10966
New York City	nyc09	1	1	371.7725
Seattle	sea01	1	1	371.7725
Seattle	sea01	2	2	371.7725
Seattle	sea01	3	3	371.7725
Seattle	sea02	1	4	33.55002
Seattle	sea02	2	1	40.38834
Seattle	sea02	3	1	40.94634
Seattle	sea03	1	1	32.70395
Seattle	sea03	2	1	39.31922
Seattle	sea04	1	1	100.4316
Seattle	sea04	2	1	97.1574
Seattle	sea06	1	1	27.63522
Seattle	sea06	2	1	27.68602
Seattle	sea06	3	2	14.91134
Seattle	sea06	4	1	11.12522
Seattle	sea07	1	1	24.10462
Seattle	sea07	2	1	19.20242
Seattle	sea07	3	1	31.9987
San Francisco	sfo01	1	1	33.19941
San Francisco	sfo01	2	2	19.28238
San Francisco	sfo01	4	2	19.28239
San Francisco	sfo02	1	2	37.03787
San Francisco	sfo02	3	2	37.03787
San Francisco	sfo04	1	1	190.875
San Francisco	sfo04	2	1	222.4533
San Francisco	sfo05	1	1	240.2139
San Francisco	sfo05	2	1	29.70322
San Francisco	sfo05	3	1	40.86013

San Francisco	sfo05	4	1	40.86013
San Francisco	sfo06	1	1	25.60322
San Francisco	sfo06	2	1	48.55373
San Francisco	sfo07	1	4	59.14551
Sacramento	smf02	1	1	37.45216
Sacramento	smf03	1	2	27.5885
Sacramento	smf03	2	2	22.27259
Sacramento	smf04	1	1	43.44838
Sacramento	smf04	2	1	16.45922
Sacramento	smf04	3	1	16.45922
Sacramento	smf05	1	1	25.04442
Sacramento	smf06	1	1	16.83711
Sacramento	smf06	2	2	11.55702
Sacramento	smf06	3	1	16.15442
Sacramento	smf07	1	1	43.28162
Sacramento	smf08	1	1	38.30482
Sacramento	smf08	2	1	13.63982
Sacramento	smf08	3	1	10.08382
Sacramento	smf09	1	1	75.4569
Sacramento	smf10	1	1	32.68982
Sacramento	smf10	2	1	32.68982
Sacramento	smf11	1	1	30.20062
Sacramento	smf11	2	1	30.20062

References

Bourgeois, D., C. F. Reinhart and G. Ward (2008). "A Standard Daylight Coefficient Model for Dynamic Daylighting Simulations." Building Research & Information **36**(1): 68 - 82.

CEC (2008). Title 24, Part 6, of the California Code of Regulations, Energy Efficiency Standards for Residential and Nonresidential Buildings California Energy Commission.

Inoue, T., T. Kawase, I. Ibamoto, S. Takakusa and Y. Matsuo (1988). "The development of an optimal control system for window shading devices based on investigations in office buildings." ASHRAE Transactions **104**: 1034 -1049.

Koti, R. and M. Addison (2007). An assessment of aiding DOE-2's simplified daylighting method with Daysim's daylight illuminances. American Solar Energy Society Annual Conference 2007, Cleveland, Ohio, USA.

Laouadi, A., C. F. Reinhart and D. Bourgeois (2008). "Efficient calculation of daylight coefficients for rooms with dissimilar complex fenestration systems." Journal of Building Performance Simulation **1**(1): 3-15.

Perez, R., R. Seals and J. Michalsky (1993). "All-Weather Model for Sky Luminance Distribution - Preliminary Configuration and Validation." Solar Energy **50**(3): 235-245.

Reinhart, C., J. Mardaljevic and Z. Rogers (2006). "Dynamic Daylight Performance Metrics for Sustainable Building Design." LEUKOS **3**(1): 1-20.

Reinhart, C. F. (2004). "LIGHTSWITCH 2002: A model for manual and automated control of electric lighting and blinds." Solar Energy **77**(1): 15-28.

Reinhart, C. F. and M. Andersen (2006). "Development and validation of a Radiance model for a translucent panel." Energy and Buildings **38**(7): 890-904.

Reinhart, C. F. and K. Voss (2003). "Monitoring Manual Control of Electric Lighting and Blinds." Lighting Research & Technology **35**(3): 243-260.

Reinhart, C. F. and O. Walkenhorst (2001). *"Dynamic RADIANCE-based Daylight Simulations for a full-scale Test Office with outer Venetian Blinds."* Energy & Buildings **33**(7): 683-697.

USGBC, U. G. B. C. (2006). "LEED-NC (Leadership in Energy and Environmental Design) Version 2.2." from www.usgbc.org/LEED/.

Vartiainen, E. (2001). "Electricity benefits of daylighting and photovoltaics for various solar facade layouts in office buildings." Energy and Buildings **33**: 113-120.

Ward, G. and R. Shakespeare (1998). Rendering with RADIANCE. The Art and Science of Lighting Visualization, Morgan Kaufmann Publishers.

Winkelmann, F. C. and S. Selkowitz (1985). "Daylight simulation in the DOE-2 building energy analysis program." Energy and Buildings **8**: 271-286.

C-5 Daysim File Preparation Process

The report reproduced in this section outlines the process of preparing files for the Radiance/DaySim simulation method that was originally used for the simulation studies.

How to Prepare Simulation Input Files For Each Space

(prepared by Christoph Reinhart)

The basic approach for the Daylight Simulations work in the CEC Daylighting Metrics project will be divide the work into two parts (see Figure 1). Initially Ecotect models of all spaces will be generated by HMG and other project partners following the modeling instructions laid out in this document. The Ecotect models will then be exported into Radiance/Daysim and the resulting Radiance and Ecotect files for all models will be uploaded onto an NRC sever. NRC will then prepare a set of scripts that automatically performs annual daylight simulations of all spaces using Radiance/Daysim and calculates new and existing daylight performance metrics such as continuous daylight autonomy and useful daylight illuminances.

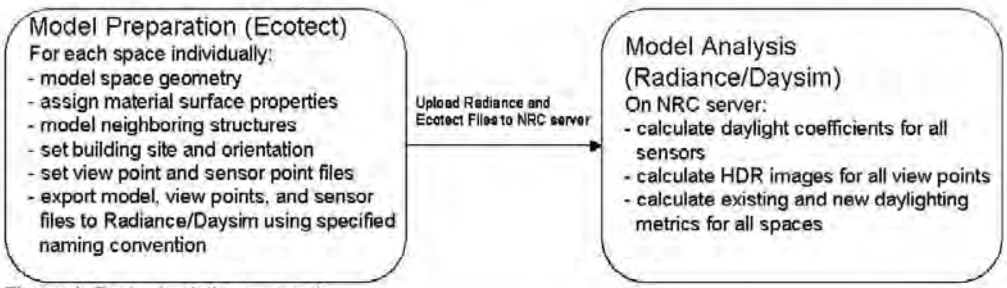


Figure 1: Basic simulation approach.

This document provides detailed instructions for the Ecotect modelers as to how the spaces should be modeled, how materials should be assigned and how the output files should be named.

For the success of this project it is crucial that these instructions are followed in order to ensure that all models of equally high quality. In case you are not sure about how to model a specific space, please contact Christoph Reinhart at christoph.reinhart@nrc-cnrc.gc.ca.

(1) Software Installation

This instructions assume that you have Ecotect, Radiance, and Daysim installed on your computer and that you have made the *NRC Lighting Material Library* is your default library in Ecotect. A getting started document describing the general capabilities of these programs and how to install them on a Windows PC is available under: http://irc.nrc-cnrc.gc.ca/ie/lighting/daylight/daysim/GettingStarted.pdf.

(2) Preparing the Ecotect model

2.1 Model Properties

Initially you should select the building location and orientation of you model (Ecotect >> Model >> Model Settings) as explained in the Ecotect help files. Note:

You can download thousands of climate files from http://www.eere.energy.gov/buildings/energyplus/cfm/weather_data.cfm and import them into Ecotect.

2.2 Model the Space Geometry

Model the geometry of the space as closely as you can paying especially attention to the thickness of external wall, mullions and structural elements near windows and skylights that strongly influence the daylight within the space. Larger pieces of furniture as well as partitions should be modeled as well.

2.3 Assign Surface Materials

If you have the NRC Lighting Material Loaded as your default Ecotect material library, you will automatically set ceiling, walls, and floors to some reasonable reflectance levels. Ideally, you should measure the diffuse reflectance of all surface in each space using a reference surface and a luminance meter. Try to also estimate the visual transmittance of all glazings. In order to customize the reflectance of a surface in Ecotect click on the Ecotect material editor and assign the color of the internal and exterior surfaces for your material (see Figure 2).

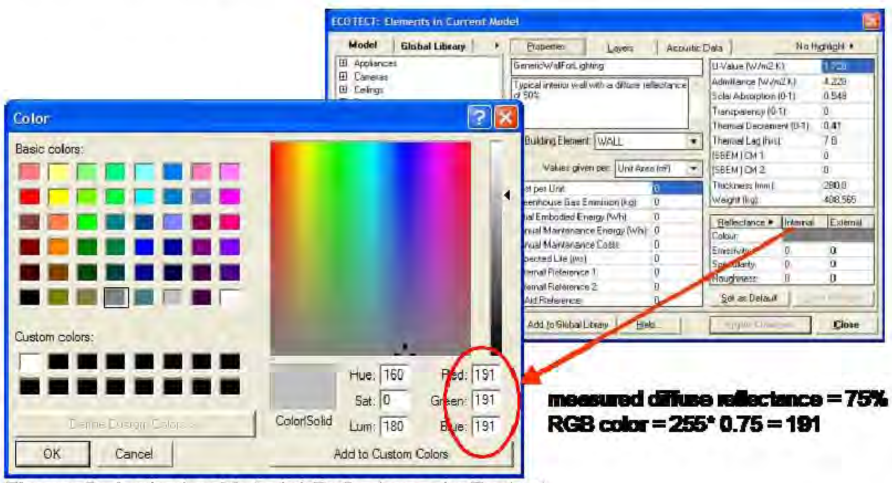


Figure 2: Assigning Material Reflectance in Ecotect.

For all clear and translucent surfaces estimate the visual transmittance (using e.g. two illuminance meters (one outside, one inside)) and give the material the the following material name: 'Type_VisualTransmittance'. E.g. if a double glazing is 'clear' with a visual transmittance of 68% the material name should be: ClearGlazing_68 (see Figure 3). A translucent glazing with a visual transmittance of 23% should be named 'TranslucentGLazing_23'.

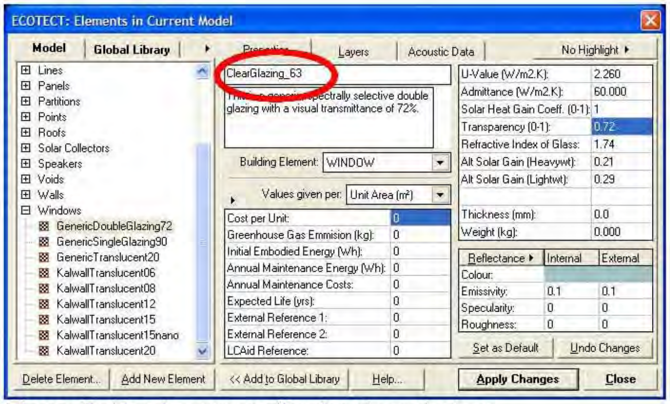


Figure 3: Naming convention for clear glazings.

2.4 External Obstructions

Do not forget to model all external obstructions (buildings and landscape) that decisively influence the daylight within your space.

2.5 Set Sensor Points and View Points

Define an illuminance grid on the work plane as well as Radiance viewpoints within your Ecotect model (see Figure 4).

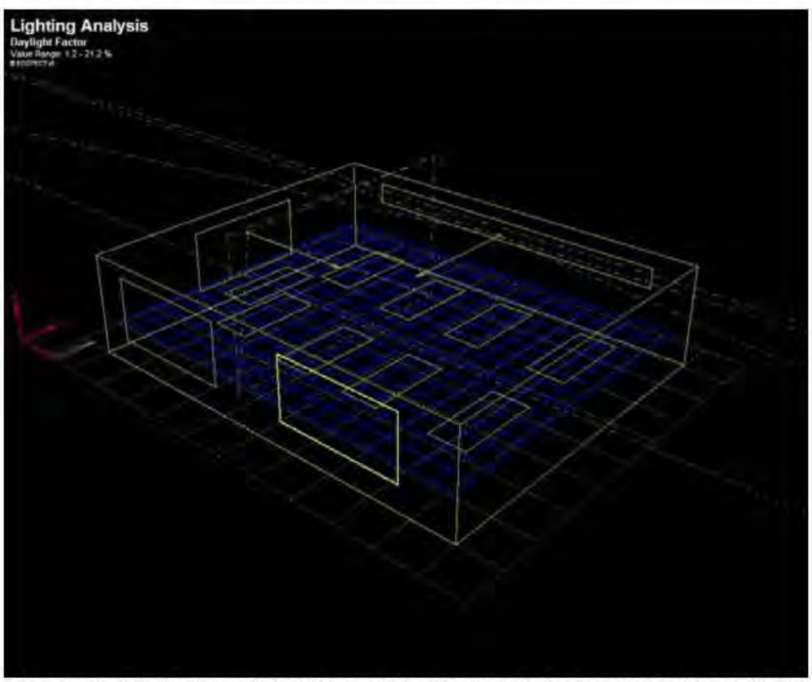


Figure 4: Ecotect model with a grid of upward facing work plane illuminance sensors (blue) and two Radiance view points (while arrows).

Note, the exact conventions used for sensors and viewpoints still have to be determined!

2.6 Export Radiance files

Export the Radiance scene files, sensor point files and view points following the following naming convention:

- Space##.##_WorkPlaneIlluminanceSensors.pts: Radiance sensor point file for a grid of upwards facing illuminance sensors at work plane height.
- Space##.##__RadianceScene.rad: Radiance scene file including geometry and material descriptors
- Space##.##__ClimateFile_5min.wea: Daysim annual climate file with a five minute time step
- Space##.##.eco:- Ecotect File of the space

E.g. in Building number 01, space 03, the Ecotect file name would be Space01.03.eco.

Please follow the exact naming convention suggested here including capitol and minor letters (Linux pays attentions to these).

C-6 SimBuild 2010: Dynamic Radiance Development Process

Dynamic Radiance – Predicting Annual Daylighting with Variable Fenestration Optics Using BSDFs

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ABSTRACT

Existing annual daylight simulation software fall short with respect to variable fenestration optics that change interior daylight distribution with sun position and/or operating schedule, thus limiting the ability to compare the performance of advanced fenestration systems. Many of these window or skylight systems can be described efficiently as a bidirectional scattering distribution function (BSDF), which characterizes their flux output as a function of input for a particular configuration. In this paper, we describe a new method that employs measured or simulated BSDFs to permit fast, matrix-based annual daylighting calculations. The matrices themselves are precomputed by Monte Carlo ray-tracing in a modified daylight coefficient approach we call *Dynamic Radiance*. The inner time-step loop then consists of multiplying the desired sky luminance vectors against three matrices in the general case, where a separate BSDF matrix permits dynamic fenestration control strategies. In this paper, the authors describe their implementation of the Dynamic Radiance method and demonstrate its application to a set of 61 real spaces modeled for a research project to determine new daylight metrics. We present results from these simulations and discuss advantages and limitations of the new approach.

Introduction

It is well understood that energy savings and electric demand reduction potential of daylighting is substantial. However, accurately predicting daylighting at an hourly time-step, for an annual simulation, is not a simple task. This was the task at hand for the Daylight Metrics Project [Heschong et al. 2010, Saxena et al. 2010], a reseach project to develop a set of simulation-based metrics to describe daylighting in architectural spaces. The simulation task required annual daylighting simulations for 61 surveyed spaces in six cities across the United States.

Initially a research version of *DaySim DDS* version 2.4 [Bourgeois et al. 2008] was choosen to perform the annual simulations, as it would provided the most modeling accuracy and supported parametric studies. However, mainly due to limitations in *DaySim's* modeling assumptions for window shadings such as blinds and fabric shades (hereon called blinds for brevity), the project team decided to use an alternative progam. While *DaySim* had the ability to operate blinds according to a solar trigger, it was limited to one schedule for all blinds in a given space, irrespective of their orientation. Furthermore, simplified assumptions of blinds light transmittance (20% diffuse, 0% direct) were found to be too simplistic. While *DaySim 2.4* does support the simulation of blinds explicitly [Reinhart et al. 2001], that approach was not used due to additional demand on computation-time. Changes were made to the research vesion of *DaySim 2.4* to enable more than one blind schedules, ultimately, achieving full functionality for the new blinds operation and output functions in *DaySim* was found to be beyond the resources of the project team.

Considering many alternatives, the project team eventually decided to commission development of a new annual simulation approach using Radiance. This approach, which for the purposes of this paper we call *Dynamic Radiance*, would build on *DaySim's* achievements and use a similar daylight coefficient methodology. The Dynamic Radiance method provides the desired blinds-operation functionality, blinds light transmittance, and data ouput. It also adds an important new capability—the ability to model variable fenestration optics that change interior daylight distribution with sun position and/or operating schedule (dynamic fenestration performance).

BI-directional scatter distribution functions (bsdf)

Central to this capability of modeling dynamic fenestration performance, is the use of Bi-directional Scatter Distribution Functions or BSDFs.

A full BSDF, as defined for WINDOW 6, consists of a full Klem sample, or a 145x145 matrix, defining light transmittance through a fenestration assembly. Incoming light striking the exterior surface of the assembly is represented through 145 exterior vectors. Similarly, light transmitted by and exiting the assembly is represented through 145 interior vectors, as shown in Figure 52. A BSDF file defines coefficients (c ≥0) to allocate light from each exterior vector to each interior vector. These coefficients are stored in a 145x145 table. Each columns represent a single exterior vector, while each row represents a single interior vector. The light transmitted into the space on any one interior vector is given by Eq. (1) below

$$I_j = \sum_{k=1}^{145} c_{jk} E_k \qquad (1)$$

Where:

E_k = light along exterior vector k
I_j = light along interior vector j
c_{jk} = coefficient relating I_j to E_k which is stored in the cell located in column k, row j of the BSDF

Our implementation of the Dynamic Radiance method utilizes BSDF files to represent fenestration assemblies consisting of the glazing and window coverings. Previous research has shown BSDF data provides acceptable resolution for simulating complex fenestration assemblies [Konstantoglou et al, 2009]. Further discussion of the file format is available from LBNL [Jonsson, 2009; Fernandes, 2006].

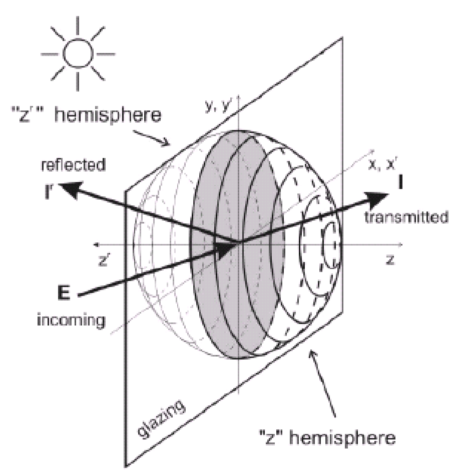

Figure 52: Schematic Diagram representing interior and exterior vectors of a BSDF [Fernandes, 2006]

Dynamic Radiance

Radiance is a lighting simulation and rendering system that was first released by the Lawrence Berkeley National Laboratory in 1989, and has undergone continuous modification and improvement since. Now in its 20th release, *Radiance* 4.0 includes the ability to predict the performance of complex window fenestration systems, defined as the BSDFs just described. To be clear, there is no identifiable program called "Dynamic Radiance." We have merely created a set of custom scripts and Makefile's that apply the tools already present in *Radiance* 4.0. The method we are calling Dynamic Radiance is not distributed separately, does not have a user interface, and would have to be substantially modified for a different set of building analyses. The basic tools we will introduce, **rtcontrib**, **genklemsamp**, **genskyvec**, and **dctimestep**, are all part of *Radiance* 4.0, and we are using them to illustrate this overall approach, which we call Dynamic Radiance.

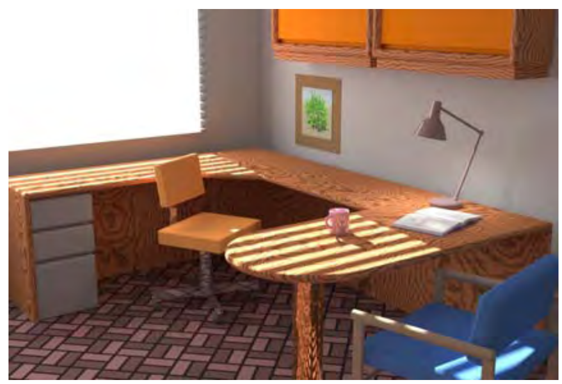

Figure 53: A full simulation using a BSDF on a window with venetian blinds that took 17 hours to generate

In a more traditional mode, the BSDF is used in *Radiance* to represent a window as a "light source" in a backwards ray-tracing calculation of interior illumination. This requires the use of the *Radiance* **mkillum** program, which has been able to interpret BSDF files since the last release. Using this process, high-quality renderings may be obtained as shown in Figure 53, which took 17 hours to generate on a single processor. However, since daylight is a dynamic phenomenon, creating a view of a single point in time is of limited use, and we would prefer a collection of renderings or animations showing how our environment reacts to changing sky conditions. Ideally, we would plot this information over an entire year based on appropriate weather data. In the case of an operable shading system, we may even wish to compare different control algorithms as part of our analysis. If it takes hours to evaluate each time step, this type of annual daylight simulation would be impractical and forbidden to us.

In the past two decades, researchers have been exploring *daylight coefficients* as a means to faster annual calculations in complex spaces [Reinhart, Mardaljevic, etc.]. In this approach, the sky is subdivided and the connection or form factor between sky patches and interior illuminance values (typically) are computed. Since light is linear, it is then a simple matter to multiply the sky luminance values for a particular condition by these coefficients and sum them together to obtain the desired, corresponding interior illuminances. This can be expressed as a matrix equation whose input is the sky vector corresponding to patch luminances at a particular time, and after passing through our daylight coefficient matrix, gives us a vector of predicted illuminance values:

$$\vec{\mathbf{i}} = \mathbf{C}\vec{\mathbf{s}} \tag{2}$$

Where:

i = resultant illuminance vector (N values)
C = daylight coefficient matrix (N rows by M columns)
s = sky luminance vector (M patch values)

The difficulty we face applying this technique to complex fenestration is two-fold. First, the calculation of the matrix **C** becomes intractable when the interactions at the window involve multiple reflections. Second, in the case of an operable shading system, we would like to be able to modify **C** as we adjust the system, calculating a different version of it for each shade position. This only exacerbates the first problem. What we need is a reformulation of the problem, which allows for the easy substitution of different shading conditions as BSDF's, and also factors the original **C** matrix into more easily calculated components. This is the revised formulation we use in our Dynamic Radiance method:

$$\vec{\mathbf{i}} = \mathbf{VTD}\vec{\mathbf{s}} \tag{3}$$

Where:

V = a "view matrix" that defines the relation between measurements and exiting window directions (N rows by K columns)
T = the transmission portion of the BSDF (K rows by L columns, usu. K = L)
D = the "daylight matrix" that defines the relation between incoming window directions and sky patches (L rows by M columns)

The **i** and **s** vectors are the same as above; we have simply factored the **C** matrix into three component matrices. The transmission matrix **T** is given as input, so all we really need to compute are the **V** and **D** matrices. For both problems, we employ the *Radiance* **rtcontrib** program.

The rtcontrib Program

Radiance performs its lighting calculations by following rays backwards from the point of measurement and into the scene in search of illumination sources, which are specified as input along with the scene's geometry and materials. The basic **rtrace** tool takes a ray origin and direction for example, and computes its radiance (the radiometric equivalent of luminance) by following the ray into the scene to see what it intersects. If the ray intersects a diffuse surface, for example, additional rays are spawned to the light sources to determine the surface illumination, whereby the outgoing radiance can be determined from reflectance. (The full calculation is a bit more complicated, involving multiple diffuse reflections and so on.)

What if we wanted to know how the outgoing radiance would change as a function of light source intensities? Say we have multiple, dimmable fixtures, which we wish to control continuously to optimize lighting in our space. Recomputing an entire image of radiance values, for each pixel corresponds to at least one ray, would be rather time consuming. It would be better and faster to compute one image for each light source, then add them together as components in our final result. Many people have taken advantage of the linearity of light to do exactly this, but with **rtcontrib**, we have an even more efficient route to such a solution.

Recomputing an image multiple times with different light sources involves many of the same ray intersections with surfaces, especially in the case of multiple diffuse interreflections. We can short-cut this process by computing our multiple images in a single step! We simply identify each light source in our scene that corresponds to a desired image, and **rtcontrib** does the rest. Moreover, we can subdivide exitant directions from our light sources, thereby allowing us to modify luminaire spatial output distributions. In applications such as directable theater lighting instruments, this would be an obvious advantage, but in our case, we want to know how different light output from our windows affects the interior illumination, which is the **V** matrix in the equation above.

Computing the View Matrix (V)

The view matrix **V** defines the relation between a particular set of sensors and a window group. The sensors may be a set of illuminance points on the workplane or ceiling, or an entire image of radiance directions from a particular viewpoint. The window group may be a single opening or a skylight, or a portion of a segmented window, or multiple windows all facing the same direction. The decision of how to group windows may be dictated by geometry, or the desire to control shading (such as blinds) independently, or other factors. At a minimum, we need a separate group for each window orientation, since we use the surface normal to anchor our directions. Figure 54 shows the contributions from the leftmost bay window of one of our test models, assigning a different random color to each of 145 output directions. Each bay window would require a different group, since they have independent orientations, but the two windows to the left of the bay could be placed into one group if desired.

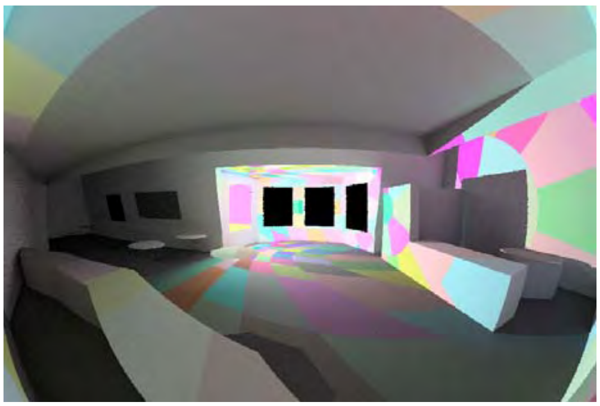

Figure 54: A rendering showing the different output directions for a single window group

Because **rtcontrib** permits output based on direction and material grouping, a single run can produce all the desired **V** matrices corresponding to every window group, and this calculation needs to be done only once per unique interior geometry. Depending on the length of the desired **i** sensor vector, scene complexity, and window groups, this step takes anywhere from under a minute to several hours. The scene above took about three hours to compute for 145 directions for each of 7 window groups feeding 426,400 sensors (pixels in an 800x533 image). That's about 426 million coefficients, which we packed into 1015 Radiance pictures (662 MBytes).

The advantage is that a final image for a particular shade and sky condition can be computed in about 10 seconds. Figure 55 shows one such time step.

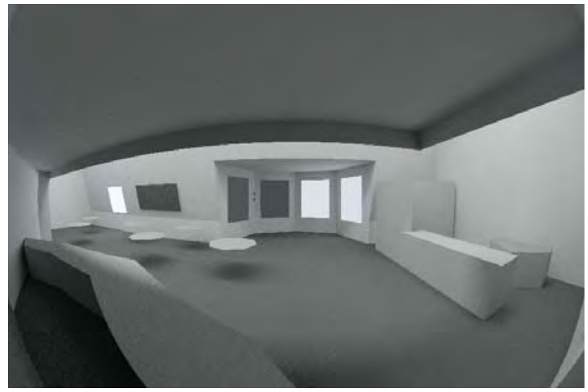

Figure 55: A combined result based on a particular time of day, year, and shading condition that took 10 seconds to generate

Computing the Daylight Matrix (D)

The calculations above rely on knowing how light is arriving at each window, which then passes through the BSDF matrix **T** for that group. These form factors are stored in the **D** matrix in Eq. (3), which relates sky patch luminances to incident window directions, accounting for external obstructions and interreflections. In fact, a separate **D** matrix is computed for each window group, since the set of directions is different for different orientations. The more general version of Eq. (3) is therefore

$$\vec{\mathbf{i}} = \sum_{g=1}^{n} \mathbf{V_g T_g D_g} \vec{\mathbf{s}} \tag{4}$$

Where:

g = window group index
n = number of window groups

The actual calculation of **V** uses **rtcontrib** to sample outgoing ray directions for each window group, collecting results for each sky patch. To assist this process, we have written a Perl script **genklemsamp** that identifies windows with a given orientation in a given geometry file, then sends out rays with random origins distributed over their surface(s). We employed the full (145x145) Klems basis described in the WINDOW 6.1 / THERM 6.1 Research Version User Manual for our sample directions, since it corresponds to the BSDF data available to us from *WINDOW6* [Windows & Daylighting Group, 2006].

Figure 56 shows the exterior of the space we showed earlier. The circled bay window was used in the fisheye projection shown in Figure 57. We assigned a random color to the 145 Tregenza patches (plus one for the ground), and overlaid a grid corresponding to the 145 Klems patches on the window. The visible surfaces appear grayish because they see most of the sky, so the coloration averages out. Hence, the corresponding rows in our **D** matrix will have many non-zero terms. The rows that correspond to direct views of the sky will have only a few non-zero terms, since only a few Tregenza patches are visible from each. Of course, it would be unwise to generate the **D** matrix directly from such an image, as it samples only a single point on the window. Our Perl script therefore randomizes the sample ray origins over the window to obtain a good average for each matrix coefficient.

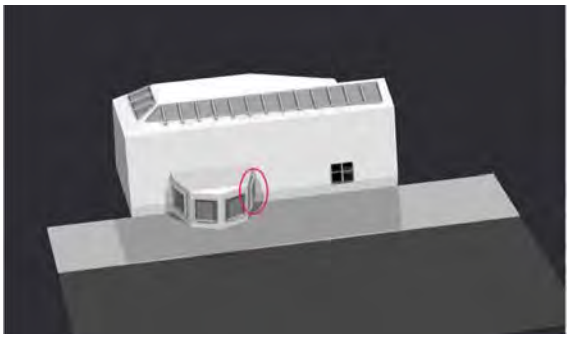

Figure 56: The exterior of our example space, indicating the window whose view is shown in Figure 57 below

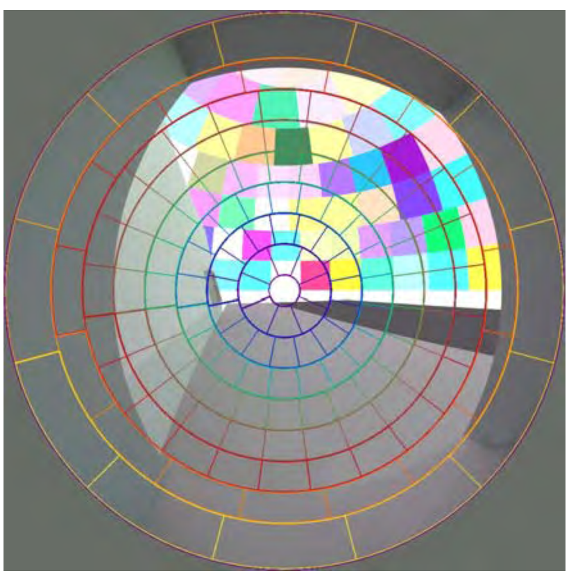

Figure 57: The grid lines divide our hemisphere into 145 patches using the full Klems basis. Randomly colored patches in the sky indicate the 145 Tregenza patches

It was discovered early on that, even if the shading system on the window is fairly diffusing and blocks any direct sunlight, 145 sky patches was not enough in cases where there was shadows cast by nearby geometry. The Tregenza resolution is roughly 12°, and we distribute the sun's energy into the three nearest patches, so the actual resolution is closer to 24°. If a neighboring building or structure is going to partially or fully block direct sun on the window, 24° is a pretty wide margin of error, and we noticed significant discrepancies in our early results. We found it necessary for many models to subdivide the sky further, and ended up using a 4x4 subdivision of the Tregenza patches developed by other researchers [Mardaljevic 2000, Bourgeois et al. 2008]. With 2305 patches (plus ground), we have an effective resolution of about 6°, corresponding roughly to a half hour in terms of solar position. Greater accuracy is of course possible with a finer subdivision, but we found this to be adequate to our needs

Sky Patch Vectors and Evaluation

Once we have our **Vg** and **Dg** matrices, and have selected the transmission matrices **Tg** for each window group, we can apply them directly in Eq. (4) or multiply and sum them together to arrive at a complete daylight coefficient matrix needed for our original Eq. (2):

$$\mathbf{C} = \sum_{g=1}^{n} \mathbf{V_g T_g D_g} \tag{5}$$

In either case, we need a sky patch vector **s** corresponding to the current time step to compute a final result vector **i**. For this purpose, we have created another Perl script **genskyvec** that takes a sky model produced by the Radiance **gensky** program or **gendaylit** by the ISE in Freiburg, Germany. The advantage of the latter program is that it takes direct and indirect solar irradiance as input and computes the sky type from these data, which one can find in reference weather files for most climates.

The final evaluation involves multiplying the combined matrix by our sky vector, which is a very fast calculation. Even when different **T** matrices are being tried at each timestep to find an optimal result, the full matrix multiplication takes only a few seconds, and a convenient tool **dctimestep** is provided for this purpose.

Using Dynamic Radiance on 61 Models

We applied the Dynamic Radiance approach to generate annual results for illuminance, sun penetration, and skyview for the Daylight Metrics project. A field survey provided detailed information to create detailed *Radiance* .rad scene files for 61 spaces in six different cities across the United States. The .rad files were created using *Ecotect v5.50*. Horizontal illuminance sensors were provide at 1 ft by 1 ft spacing, on the task level (31 inches), eye level (48 inches) and ceiling level (height varies by space)

After the models were exported from *EcoTect* the windows were grouped in each space by orientation. In addition, we further limited groups to windows which were co-planar, contained the same glass type, and the same window covering (blinds or shades where present). Lastly, BSDF files were assigned to each window group.

For the scope of this project, we limited blinds operation to only two conditions – blinds are either fully deployed or completely retracted, a deployed blind completely covers the window, while a retracted blind does not cover any portion of the window. Blinds were triggered to deploy when 2% of the horizontal ‘eye level’ sensors had an illuminance of 4,000 lux (roughly equivalent to 50 Watt/m2 of solar radiation) or greater when considering only sunlight as an illumination source from any given window group. One of two BSDF files were assigned to window groups depending on the characteristics of the windows in that group. A BSDF representing an un-shaded, or open window was assigned to all window groups. This "open" BSDF accounted for the visible transmittance of the glazing in the windows. If the windows in the group had blinds or shades, an additional BSDF was assigned to the group to reflect the "closed" condition. This BSDF accounted for the visible transmittance of the glazing and the associated blinds or shades. Other details of blinds assumptions used in the project can be found here [Saxena et al, 2010].

The simulations using the Dynamic Radiance approach took between 2 and 14 hours for 80% of the models with a median time of 5.2 hours. The quickest model finished in just under an hour. The space had only one window, and had little exterior context modeled. The longest model took just over 28 hours. It was a relatively large model, had 18 window groups, and was surrounded by multiple high-rise skyscrapers. Processor run times were not recorded for all models, however, of the 41 timed runs, only 3 took longer than 14 hours.

Simulation Results

The color contour plots in Figure 58 represent average monthly illuminance for each sensor on the task level illumination grid for January for a space facing south.

The plot on the left shows illuminance without blinds, while that on the right is with blinds operated as per the blinds trigger assumption. The data were averaged separately for each hourly time step from 8:00-17:00, for the months January.

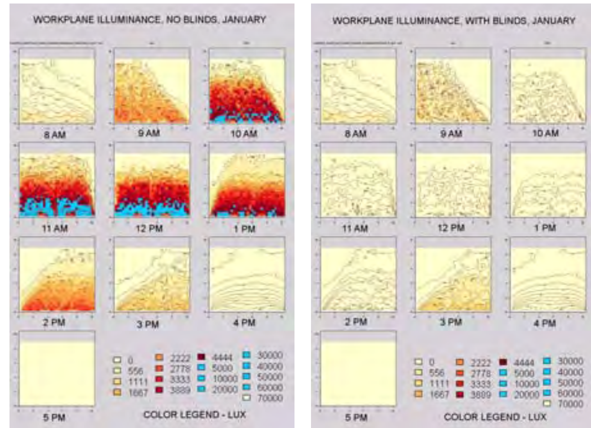

Figure 58: Average workplane illuminance in January – No blinds case (left), blinds operated case (right)

The plots clearly show that during the hours when blinds are deployed, the average illumination at the workplane is much lower with the blinds closed, as expected, but the directional nature of the light through the blinds is preserved due to the use of BSDFs.

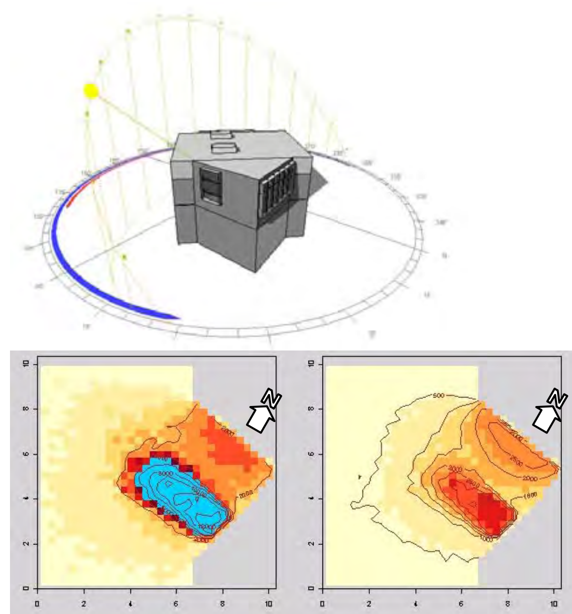

Figure 59: Illuminance distributions at 8:00 AM on July 11th - No blinds case (left), blinds operated case (right)

Figure 59 show the 3D model and illuminance plots for a space in San Francisco at 8:00 AM on July 11th. The plot on the left is without blinds, with that on the right is with blinds operated as per the blinds trigger assumptions. The space has two windows, one facing north and another facing east. As per the rule-set for defining window groups, since each window has a different orientation, two window groups were assigned, one for each window.

The illuminance plot without blinds (left) shows that at 8:00 AM, the east-facing window is receiving direct sun (shown by blue >5000 lux), while the north-facing window receives only diffuse or reflected light.

The illuminance plot with blinds operated (right) shows that, illuminance next to the east window reduces to show that blinds have been deployed, while that next to the north-facing window reamins more or less unchanged. This result is in-line with what can be expected with two window groups. Only the blinds on the east-facing window are getting deployed, while blinds on the noth-facing window reamin open.

Advantages and Disadvantages of Dynamic Radiance

Speed and the ability to incorporate arbitrary BTDFs on windows and skylights are the principal advantages of the Dynamic Radiance method. Combining daylight coefficients with window-specific BSDF data allows us to generate annual simulations in an operationally-acceptable time-span. By splitting the daylight coefficient matrix into two matrixes, an interior- and an exterior-matrix, we are able trace light paths inside and outside the building only once and reuse the results. Then, simple matrix math gives us the resultant illumination for each point with a given window matrix (BSDF) substituted in between the interior- and an exterior-matrices. This timestep calculation can be inserted into an annual simulation system without requiring direct links to Radiance, simplifying the process as well. Any controllable shading system that can be discretized into a finite number of BSDFs may be evaluated, and the control algorithm can be simple or complex, since the calculation is so quick. This opens up the possibilites to evaluate the daylighting performance of dynamic blinds and shading systems that use moroized controls and change postion based on climtic inputs.

The Dynamic Radiance approach utilizes top-level *Radiance* component programs. These programs have an established interface and years of testing. In the event that bug fixes or enhancements are added to *Radiance*, the suite of scripts and Makefile's used to implement the Dynamic Radiance approach can be updated simply by installing the current version of *Radiance*. No compilation is necessary due to the loose coupling and standard interfaces between the programs that constitute the Dynamic Radiance approach and *Radiance* 4.0 component programs.

Despite its benefits for annual simulation and complex fenestration, the Dynamic Radiance method comes with some limitations. Firstly, it does not project exterior shadows into the space, so a partially obscured window group will pass the average light reaching its exterior, evenly distributed over the area of the window group. The window may be subdivided to compensate, but doing so increases the computation time, and determining the optimal subdivision in advance is difficult. Secondly, window-assembly light-distribution patterns are limited by the BSDF format, so any direct or redirected component is smeared over about 15° with the current standard basis. This is illustrated by Figure 60, which can be compared to Figure 53 calculated by **mkillum**. We have lost the details of the blinds, and even the shadows due to the window edges have been blurred significantly. However, this took only an hour to compute, including precalculation, and the next time step can be computed in a matter of seconds.

Figure 60: The same scene as Figure 53, computed using the Dynamic Radiance approach

Acknowledgment

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References

Bourgeois, D., C.F. Reinhart, and G. Ward 2008. A Standard Daylight Coefficient Model for Dynamic Daylighting Simulations. Building Research & Information, 2008. 36(1): p. 68 - 82

Fernandes, L. 2006. Coordinate Systems for Representation of Bidirectional Optical Properties of Fenestration. Lawrence Berkeley National Lab, Berkeley, California, USA

Heschong, L., M. Saxena, and R. Higa 2010. Improving Prediction of Daylighting Performance. Proceedings of the ACEEE 2010 Summer Study on Energy Efficiency in Buildings.

Jonsson, J. C. 2009. How to Interpret the Window6 BSDF Matrix. Lawrence Berkeley National Lab, Berkeley, California, USA

Konstantoglou, M., J. C. Jonsson, and E. Lee 2009. Simulating Complex Window Systems using BSDF Data. PLEA 2009 - 26th Conference on Passive and Low Energy Architecture, Quebec City, Canada

Mardaljevic J 2000. Daylight Simulation: Validation, Sky Models and Daylight Coefficients. PhD Thesis, De Montfort University, Leicester, UK

Reinhart, C. F. and O. Walkenhorst 2001. Dynamic RADIANCE-based Daylight Simulations for a full-scale Test Office with outer Venetian Blinds. Energy & Buildings 33(7): 683-697

Saxena, M., L. Heschong, K. V. D. Wymelenberg, S. Wayland, 2010. 61 Flavors of Daylight. Proceedings of the ACEEE 2010 Summer Study on Energy Efficiency in Buildings

Windows & Daylighting Group 2006. WINDOW 6.1 / THERM 6.1 Research Version User Manual. Lawrence Berkeley National Lab, Berkeley, California, USA

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Figure 2 This text MUST be included in the body for paper submission, at the end of your paper on a separate page

C-7 ACEEE 2010 paper – 61 Flavors of Daylight

"61 Flavors of Daylight" by Mudit Saxena and Lisa Heschong, Heschong Mahone Group; Kevin Van Den Wymelenberg, University of Idaho – Integrated Design Lab; and Seth Wayland, Innovative Power Analytics.

This paper can be found at: http://eec.ucdavis.edu/ACEEE/2010/data/papers/2013.pdf

More information is available at: http://www.aceee.org/proceedings

C-8 ACEEE 2010 paper – Improving Daylighting Performance Prediction

"Improving Prediction of Daylighting Performance" by Lisa Heschong and Mudit Saxena, Heschong Mahone Group; and Randall Higa, Southern California Edison.

This paper can be found at: http://eec.ucdavis.edu/ACEEE/2010/data/papers/2012.pdf

More information is available at: http://www.aceee.org/proceedings

C-9 Simulation Methodology Summary

The following text summarizes the simulation assumptions used in this study. Further detail on methodology can be found in the survey data collection forms, and the modeling simulation instructions included elsewhere in this appendix.

C-9.1 Study Space Definition

- For each study space, the limits of the physical area used during the subjective assessments and for simulation were determined based on two criteria; to define a coherent area with some access to daylight (however little), and one large enough to include approximately 10 occupants who could be surveyed. For example, in the case of a classroom, the whole room was defined as the space, but in the case of a large open plan office, a representative area including 10 workstations was defined as the space.
- Typically these study spaces were 30 to 40 feet on a side.
- Permanent opaque partitions were used to define spaces wherever possible, or major structural elements, such as columns, window openings, or permanent shelving when partitions were not appropriate. Spaces spanned across translucent partitions.
- When a defined study space was smaller than a larger open area, all of the larger open area that also contributed to daylight distribution was also modeled as "contextual" space. Thus, for an open office study space, 10-12 cubicles would be defined as the study area for sensor grids location, but windows and space to either side were included, at least as wide as the study area.
- Architectural plans were used for dimensions when available. Otherwise site measurements from laser range finders were used.

C-9.2 Study Space Location

- The study spaces were located in three states and six urban areas: California—San Francisco/Oakland and surrounds, Sacramento and surrounds, and Truckee; Washington State—Seattle/Tacoma and surrounds; New York State—Albany and New York City and surrounds.
- Thus, the climates and locations represented varied from coastal to inland, urban to rural, and from moderate to temperate, very sunny to very overcast, with and without snowy winters.
- The latitudes however, only varied from a low of 37° (Fremont, CA) to a high of 49° (Seattle, WA), and thus observations were restricted to about a 15º band of the northern continental United States. Ideally, similar studies should extend the work to both more southern (0-35º) and more northern (50-60+º) environments.

C-9.3 Analysis Period and Weather Data

- A 10 hour day, 8AM-6PM local clock time (3,650 annual hours, accounting for daylight savings time)
  - Readings taken at the ½ hour, thus 8:30, 9:30, and so forth.
- Hourly weather (direct and global diffuse illumination) was derived from TMY2 data for the nearest available weather station.
- Perez sky with 2305 sky patches. Refer to Daysim and Dynamic Radiance reports for further details of Daylight Coefficient method.

C-9.4 Sensor Grids

- The task level grid was defined as
  - Grid height: reference 0.8m or 32″, facing up
  - Grid spacing: 1′ on center sensor location
  - Grid center: the grid is centered in the space
  - Wall offset: sensor located between 0″ to 12″ offset from wall
- The eye level grid was defined as
  - Grid height: reference 48″, facing up
  - Grid spacing: 1′ on center sensor location
  - Grid center: the grid is centered in the space
  - Wall offset: sensor located between 24″ to 12″ offset from wall
- The ceiling level grid was defined as
  - Grid height: highest continuous horizontal plane in the space, facing down
  - Grid spacing: 1′ on center sensor location
  - Grid center: the grid is centered in the space
  - Wall offset: sensor located between 0″ to 12″ offset from wall

C-9.5 Blinds/shades Operation Schedule

- All windows that actually had blinds were modeled with blinds, likewise for roller shades.
- Blinds/shades are closed (by window group) to block sunlight on an hourly basis when 2 percent of eye level sensors exceed >1000 lux of direct sun contribution only (zero bounces in Radiance).
- A window group is defined as all windows facing the same orientation with the same exterior shading. Window groups in different planes on the same façade were also defined as separate window groups. Separate window groups were created for windows above an interior lightshelf.
- Each window group was run individually to determine the blinds operation schedule for that group.

C-9.6 Blinds/shades Transmission

- For all slated blinds (horizontal or vertical) – A BSDF file approximating 20 percent VLT for direct sunlight and diffuse skylight, assuming a static Lambertian distribution.
- For all roller shades (regardless of color or weave) – A BSDF file approximating 5 percent VLT for direct sunlight and diffuse skylight, assuming a static Lambertian distribution.

C-9.7 Furniture

- Furniture was measured and modeled if any dimension exceeded 4'. Thus, tables, shelves and workstation partitions were included. Chairs were not. Plans and photographs were used to locate furniture.

C-9.8 Room Surface Reflectances

- Surface reflectances in room were measured for multiple locations, recorded, averaged and rounded to the nearest 10 percent bins – 90 percent, 80 percent, 70 percent, and so forth.
  - Large surfaces with distinctive reflectance, such as white boards and area rugs, were measured and modeled.
- If reflectance data were missing the following assumptions were used:
  - 20 percent floor
  - 50 percent walls
  - 80 percent ceiling
  - 50 percent furniture

C-9.9 Window Details

- Any window detail (sills, jambs, mullions, shelves, overhangs) greater than 2" in any dimension was modeled as such.
- All windows were modeled with appropriate wall thicknesses.
- Exterior shading was modeled with accurate geometry and material properties. Fins, slats and bars were modeled. When the geometry was very fine, equivalent geometry was used, expanded in all directions.
- Window glazing VLT was measured and rounded to 5 percent bins.
- Skylight VLTs were estimated from product specifications, with a dirt depreciation factor added.

C-9.10 Exterior Surfaces and Obstructions

- Exterior obstructions, including building self-shading, trees and other buildings, were modeled as completely as possible.

- Tree heights were estimated via triangulation, and all trees were modeled as single planar translucent elements with 20 percent VLT
- Ground materials were modeled at a minimum distance of window head from ground. Thus, if the window was on a second floor, the ground was modeled for a distance = first floor structural height plus window head height.
- Buildings within 100 ft radius of window, or above a 20 degree profile angle, were modeled with at 10' resolution. Photographs and satellite images of the site were used to confirm dimensions.
- Urban environments were modeled included all surrounding buildings, modeled as 3D opaque obstructions, obtained from cell phone maps when available.
- Exterior surface reflectances were assigned per table in simulation instructions. The study site reflectances were based on actual materials (brick, concrete, grass) while other buildings had 20 percent reflectance, and no specular surfaces.

C-9-11 Radiance Settings

- Refer to Daysim and Dynamic Radiance reports.

APPENDIX D:
Analysis and Findings

D.1 Principal Components Analysis

The two tables below present the result of the Principal Components analysis for the occupant and expert responses to the 15 shared questions, shown for those components which explained more than 5 percent of the variance. The larger values, >0.25, are highlighted in green for positive and yellow for negative. The larger the value, the stronger the contribution to the proportion of variance explained for each pass, PC1 through PC4. Note the tighter correlations in the expert data results in a higher cumulative percentage of variance explained at each level.

Table 1: Principal Components Analysis for Matching Expert Responses

Occupant Survey PCA for questions matching expert survey only				
	PC1	PC2	PC3	PC4
Q8	-0.22	0.14	-0.15	0.01
Q9	-0.25	0.20	-0.18	0.06
Q10	-0.18	-0.18	-0.16	-0.52
Q11	-0.12	-0.17	-0.19	-0.35
Q12	-0.30	0.43	-0.01	0.27
Q13	-0.30	0.36	-0.09	0.09
Q14	-0.36	0.16	-0.13	0.17
Q15	-0.32	-0.10	-0.20	-0.11
Q16	-0.25	-0.11	-0.14	-0.25
Q17	-0.20	-0.16	-0.32	-0.09
Q18	-0.23	-0.10	0.36	-0.15
Q19	-0.33	-0.10	0.71	-0.07
Q20	-0.34	0.00	0.23	-0.08
Q21	-0.16	-0.50	-0.09	0.53
Q22	-0.20	-0.47	-0.07	0.30
Importance of components:				
	PC1	PC2	PC3	PC4
Standard deviation	5.327	3.372	2.7335	2.3143
Proportion of Variance	0.349	0.14	0.0918	0.0658
Cumulative Proportion	0.349	0.488	0.58	0.6458

Table 2: Expert Survey Principal Component Analysis for First 15 Questions

Expert Survey PCA for first 15 questions only					
expert	occupant	PC1	PC2	PC3	PC4
Q1	Q8	0.31	-0.05	0.04	-0.12
Q2	Q9	0.31	-0.06	0.11	-0.16
Q3	Q10	0.12	0.18	0.18	-0.27
Q4	Q11	0.09	0.12	0.23	-0.13
Q5	Q12	0.29	-0.16	**0.44**	0.16
Q6	Q13	0.37	-0.17	0.37	0.27
Q7	Q14	0.26	0.11	0.25	0.14
Q8	Q15	0.22	0.24	-0.01	-0.17
Q9	Q16	0.17	0.26	0.13	-0.34
Q10	Q17	0.13	0.29	-0.09	**-0.57**
Q11	Q18	0.29	-0.20	-0.21	0.00
Q12	Q19	**0.37**	-0.26	-0.45	-0.02
Q13	Q20	0.34	-0.21	-0.40	-0.05
Q14	Q21	0.15	**0.60**	-0.20	**0.38**
Q15	Q22	0.21	0.39	-0.18	0.38
	Importance of components:				
		PC1	PC2	PC3	PC4
	Standard deviation	5.365	3.167	2.745	1.8819
	Proportion of Variance	0.429	0.15	0.112	0.0528
	Cumulative Proportion	0.429	0.579	0.691	0.744

D.2 Inverse Daylight Autonomy Percentile Plots

Below is a list of the 61 spaces with some descriptive statistics. The inverse Daylight Autonomy Percentile Plots, or iDAp plots, include photos and 3D images to help understand the context of the spaces. These are further explained in the following appendix. The iDAp plots are based on a slightly earlier generation of simulation runs and are not completely consistent with the sDA data presented in the following appendix, or the final regression analysis. For purposes of visual inspection, however, the differences are trivial, and so they were not recreated.

Table 3: Index of 61 Spaces in Alphabetic Order

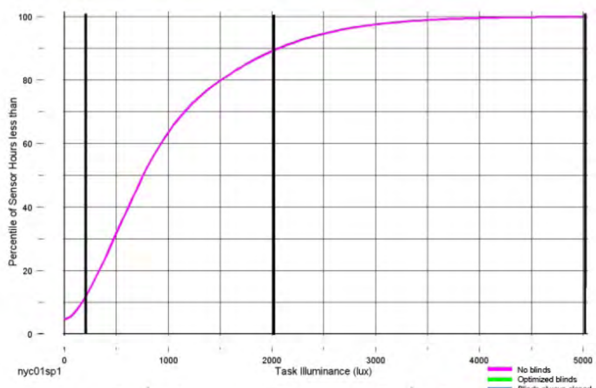
Index of 61 spaces in alphabetic order, page 1:

Order	ID	type	Space Type	Weather Locale	Latitude	Window coverings modeled	Primary View	Other daylight sources	Study area	Window to interior wall area
1	NYC01.SP1	1	Library	Albany NY	43	no blinds	large north		5155	100%
2	NYC01.SP2	2	Office	Albany NY	43	Blinds 20%	none	clerestory-2	683	16%
3	NYC02.SP1	2	Office	Albany NY	43	Blinds 20%	south		2294	15%
4	NYC02.SP2	3	Classroom	Albany NY	43	Blinds 20%	north and south		1049	10%
5	NYC04.SP1	2	Office	New York City	41	Shades 5%	south and west		3096	100%
6	NYC04.SP2	2	Office	New York City	41	Shades 5%	west and north		3147	97%
7	NYC05.SP1	3	Classroom	New York City	41	Shades 5%	southwest	light shelf	1068	19%
8	NYC05.SP2	3	Classroom	New York City	41	Shades 5%	southwest	light shelf	883	35%
9	NYC08.SP1	3	Classroom	New York City	41	Shades 5%	south	light shelf	642	38%
10	NYC08.SP2	3	Classroom	New York City	41	Shades 5%	south	light shelf	642	38%
11	NYC09.SP1	2	Office	New York City	41	no blinds	south		1034	79%
12	SEA01.SP1	2	Office	Seattle	48	blinds 20%	north		3218	52%
13	SEA01.SP2	2	Office	Seattle	48	blinds 20%	south		2779	70%
14	SEA01.SP3	2	Office	Seattle	48	blinds 20%	east		1696	56%
15	SEA02.SP1	1	Library	Seattle	48	blinds 20%	none	clerestory-4	2268	21%
16	SEA02.SP2	3	Classroom	Seattle	48	blinds 20%	south	light shelf	896	17%
17	SEA02.SP3	3	Classroom	Seattle	48	blinds 20%	south	light shelf	896	14%
18	SEA03.SP1	3	Classroom	Seattle	48	Shades 5%	south		1065	69%
19	SEA03.SP2	1	Lobby	Seattle	48	no blinds	none	Monitors	6450	32%
20	SEA04.SP1	1	Lobby	Seattle	48	no blinds	none	Monitors	2806	16%
21	SEA04.SP2	1	Multipurpose	Seattle	48	Shades 5%	west	Monitors	2343	19%
22	SEA06.SP1	2	Office	Seattle	48	Shades 5%	west		1567	50%
23	SEA06.SP2	2	Office	Seattle	48	Shades 5%	west		3052	97%
24	SEA06.SP3	3	Conference	Seattle	48	Shades 5%	west		560	47%
25	SEA06.SP4	1	Library	Seattle	48	no blinds	translucent		missing	missing
26	SEA07.SP1	2	Office	Seattle	48	Shades 5%	north	Skylights	2405	71%
27	SEA07.SP2	1	Lobby	Seattle	48	Shades 5%	south		2276	86%
28	SEA07.SP3	2	Office	Seattle	48	Shades 5%	north		2920	76%
29	SFO01.SP1	1	Library	Oakland	38	no blinds	translucent	translucent	1491	11%
30	SFO01.SP2	3	Classroom	Oakland	38	Blinds 20%	south		933	42%
31	SFO01.SP4	3	Classroom	Oakland	38	Blinds 20%	north	Skylights	933	42%

Index of 61 spaces in alphabetic order, page 2:

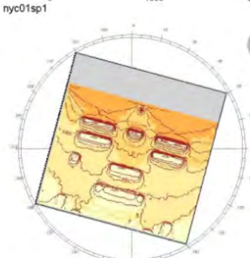
Order	ID	type	Space Type	Weather Locale	Latitude	Window coverings modeled	Primary View	Other daylight sources	Study area	Window to interior wall area
32	SFO02.SP1	3	Classroom	Oakland	38	Blinds 20%	east/west	Skylights	897	18%
33	SFO02.SP3	3	Classroom	Oakland	38	Blinds 20%	east/west		897	18%
34	SFO04.SP1	2	Office	San Francisco	38	Shades 5%	south		3344	54%
35	SFO04.SP2	2	Office	San Francisco	38	Blinds 20%	north		6100	100%
36	SFO05.SP1	2	Office	San Francisco	38	Blinds 20%	north		3145	56%
37	SFO05.SP2	2	Office	San Francisco	38	Blinds 20%	Atrium		3834	62%
38	SFO05.SP3	3	Conference	San Francisco	38	no blinds	Atrium		missing	missing
39	SFO05.SP4	2	Office	San Francisco	38	Blinds 20%	south		3145	56%
40	SFO06.SP1	1	Lobby	San Francisco	38	no blinds	none	Skylights	missing	missing
41	SFO06.SP2	1	Library	San Francisco	38	no blinds	none	clerestory -2	missing	missing
42	SFO07.SP1	1	Library	San Francisco	38	Shades 5%	none	clerestory -4	3822	17%
43	SMF02.SP1	1	Library	Sacramento	39	no blinds	south		1500	69%
44	SMF03.SP1	3	Classroom	Sacramento	39	Shades 5%	norht/south	clerestory	875	51%
45	SMF03.SP2	3	Classroom	Sacramento	39	Shades 5%	north/south	clerestory	875	47%
46	SMF04.SP1	2	Office	Sacramento	39	Blinds 20%	south	light shelf	1438	46%
47	SMF04.SP2	2	Office	Sacramento	39	Blinds 20%	north		1713	61%
48	SMF04.SP3	2	Office	Sacramento	39	Blinds 20%	north	Skylights	1713	61%
49	SMF05.SP1	2	Office	Sacramento	39	no blinds	none	Skylights	5067	0%
50	SMF06.SP1	1	Library	Sacramento	39	Blinds 20%	north	Skylights	1352	50%
51	SMF06.SP2	3	Classroom	Sacramento	39	Shades 5%	north/west	Skylights	739	31%
52	SMF06.SP3	3	Classroom	Sacramento	39	Shades 5%	south/east	Skylights	1045	30%
53	SMF07.SP1	1	Library	Sacramento	39	no blinds	north	Skylights	3774	22%
54	SMF08.SP1	3	Classroom	Tahoe	40	Blinds 20%	south	clerestory	751	47%
55	SMF08.SP2	1	Library	Tahoe	40	Blinds 20%	south	clerestory	1343	30%
56	SMF08.SP3	3	Classroom	Tahoe	40	Blinds 20%	north	clerestory	799	47%
57	SMF09.SP1	1	Multipurpose	Tahoe	40	no blinds	south/north	Monitors	4174	27%
58	SMF10.SP1	3	Classroom	Sacramento	39	Shades 5%	east/west	Tubular skylights	899	12%
59	SMF10.SP2	3	Classroom	Sacramento	39	Shades 5%	east/west		899	13%
60	SMF11.SP1	2	Office	Sacramento	39	Blinds 20%	north	Skylights	4190	83%
61	SMF11.SP2	2	Office	Sacramento	39	no blinds	none	borrowed skylight	missing	missing

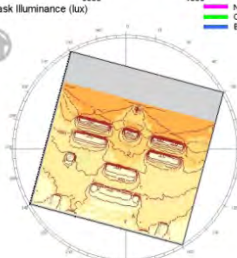
Type 1: Library   nyc01sp1   No Blinds   43°, 243/427

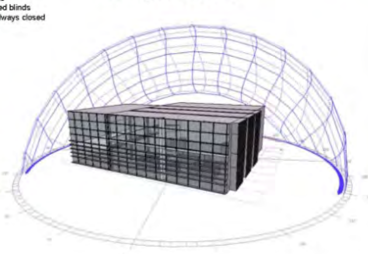


Facing northeast

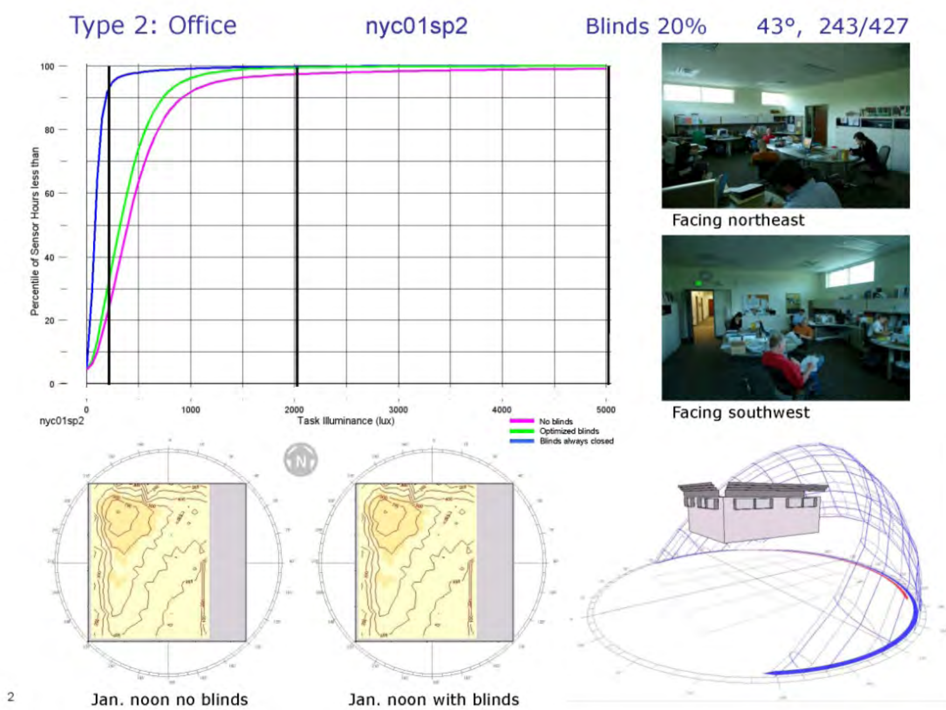
Facing northwest

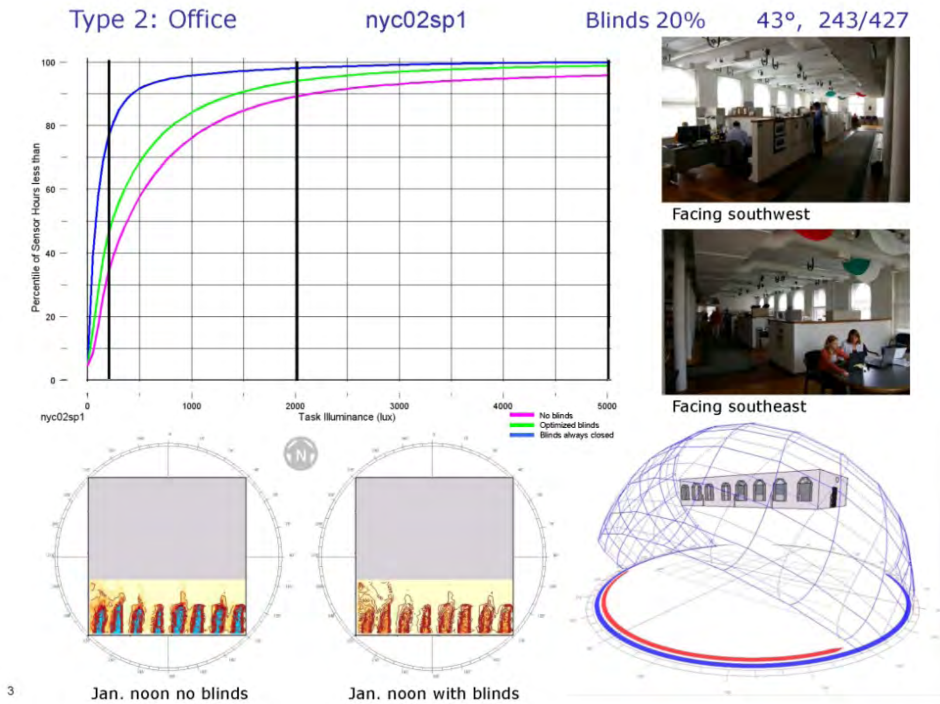


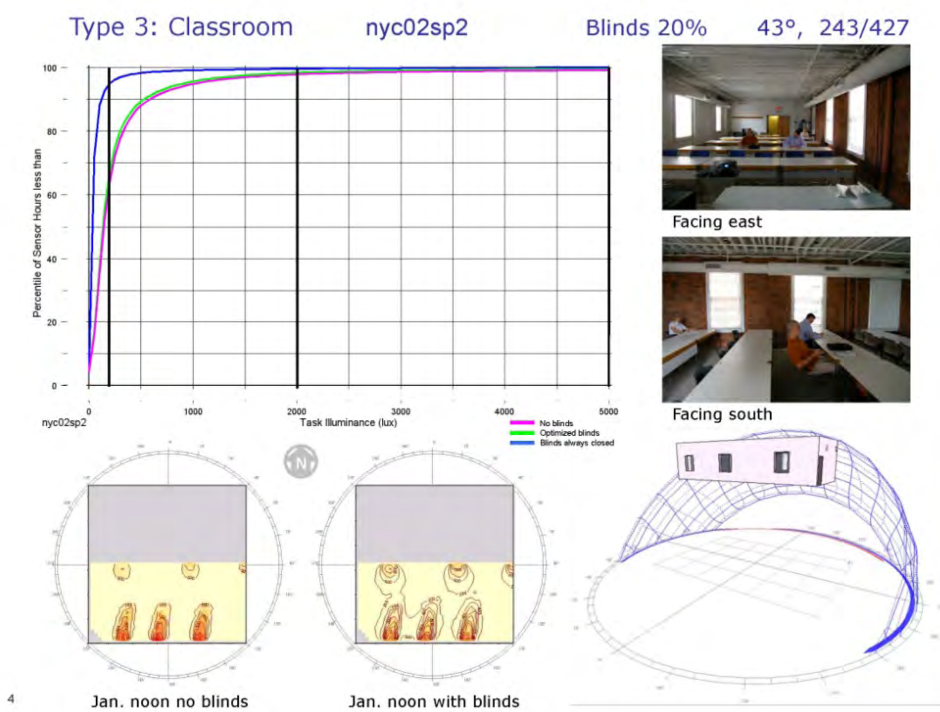


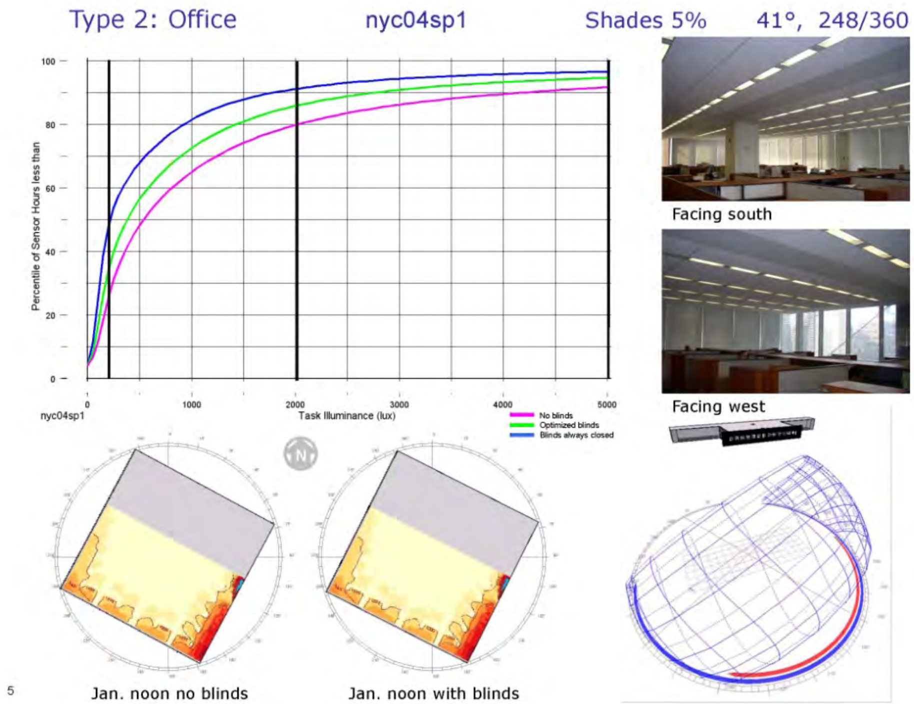


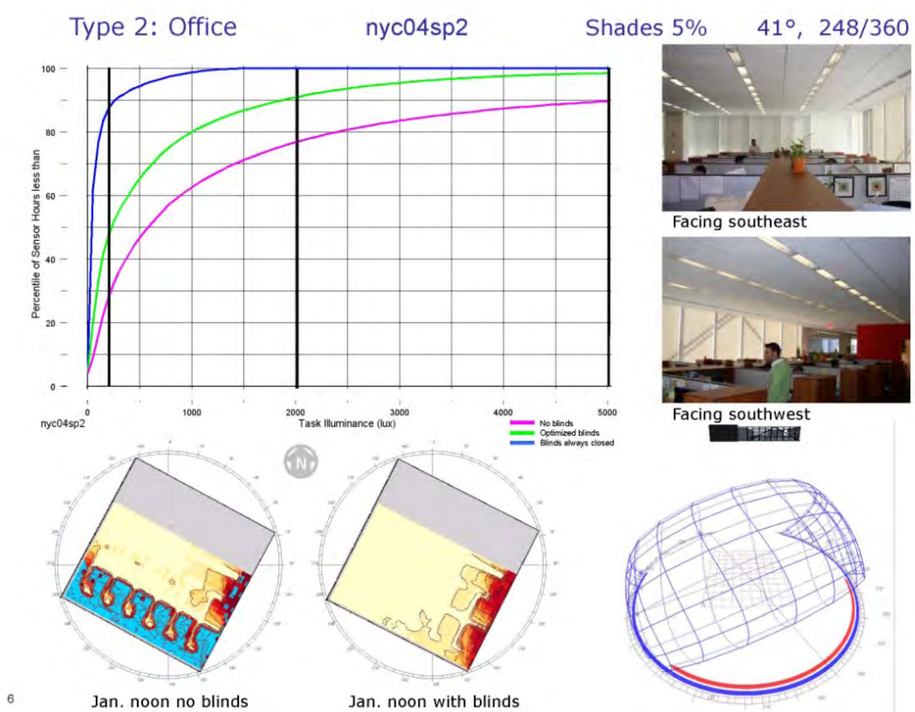
1   Jan. noon no blinds   Jan. noon with blinds


Type 2: Office
nyc01sp2
Blinds 20%
43°, 243/427
Percentile of Sensor Hours less than
Task Illuminance (lux)
nyc01sp2
No blinds
Optimized blinds
Blinds always closed
Facing northeast
Facing southwest
2
Jan. noon no blinds
Jan. noon with blinds

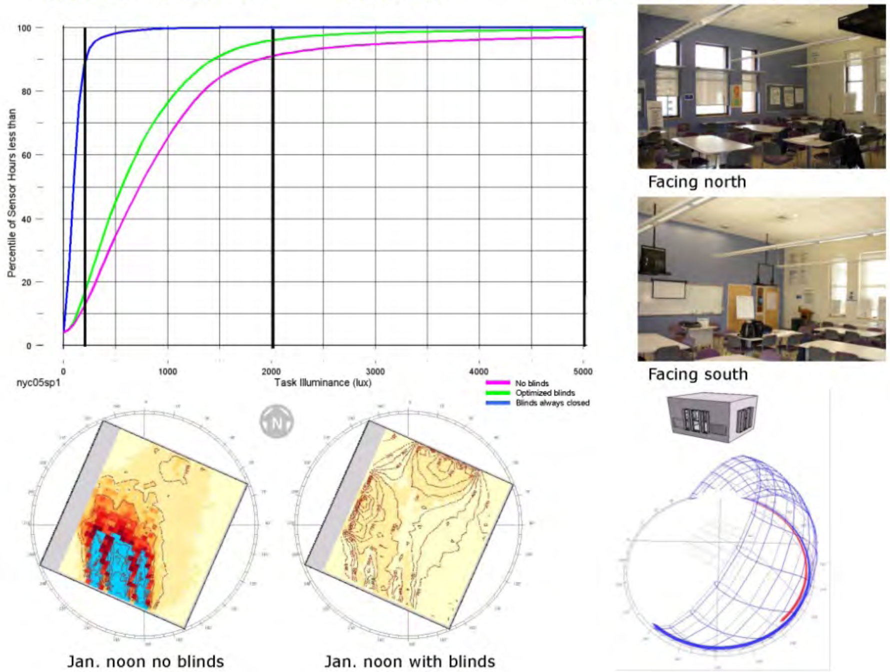

Type 2: Office
nyc02sp1
Blinds 20%
43°, 243/427
Percentile of Sensor Hours less than
Task Illuminance (lux)
nyc02sp1
No blinds
Optimized blinds
Blinds always closed
Facing southwest
Facing southeast
3
Jan. noon no blinds
Jan. noon with blinds


Type 3: Classroom
nyc02sp2
Blinds 20%
43°, 243/427
Percentile of Sensor Hours less than
Task Illuminance (lux)
nyc02sp2
No blinds
Optimized blinds
Blinds always closed
Facing east
Facing south
4
Jan. noon no blinds
Jan. noon with blinds


Type 2: Office
nyc04sp1
Shades 5%
41°, 248/360
Percentile of Sensor Hours less than
Task Illuminance (lux)
nyc04sp1
No blinds
Optimized blinds
Blinds always closed
Facing south
Facing west
Jan. noon no blinds
Jan. noon with blinds
5

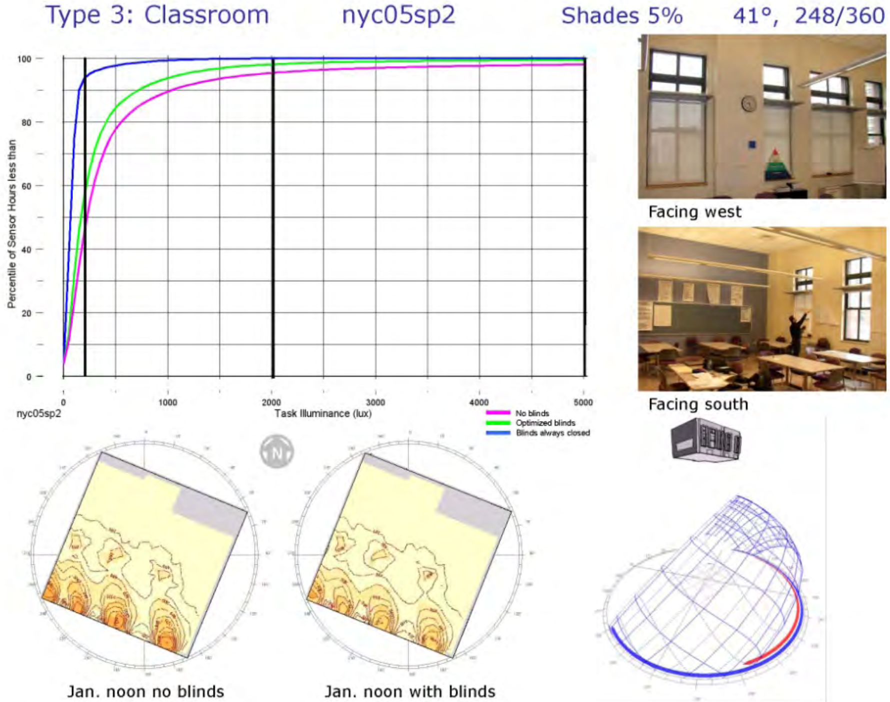

Type 2: Office
nyc04sp2
Shades 5%
41°, 248/360
Percentile of Sensor Hours less than
Task Illuminance (lux)
nyc04sp2
No blinds
Optimized blinds
Blinds always closed
Facing southeast
Facing southwest
Jan. noon no blinds
Jan. noon with blinds
6

Type 3: Classroom nyc05sp1 Shades 5% 41°, 248/360



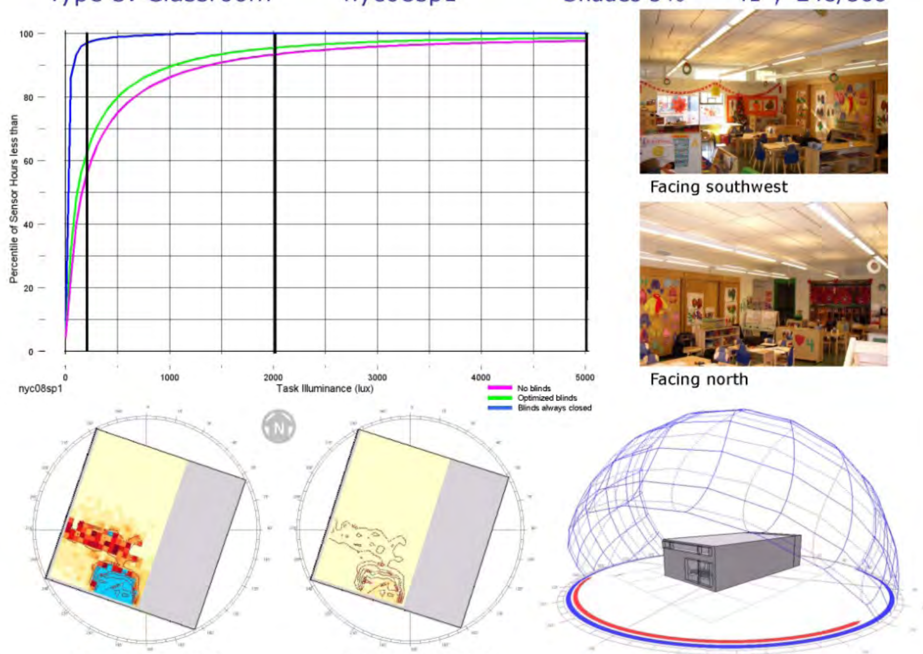
7

Type 3: Classroom nyc05sp2 Shades 5% 41°, 248/360



8

Type 3: Classroom nyc08sp1 Shades 5% 41°, 248/360

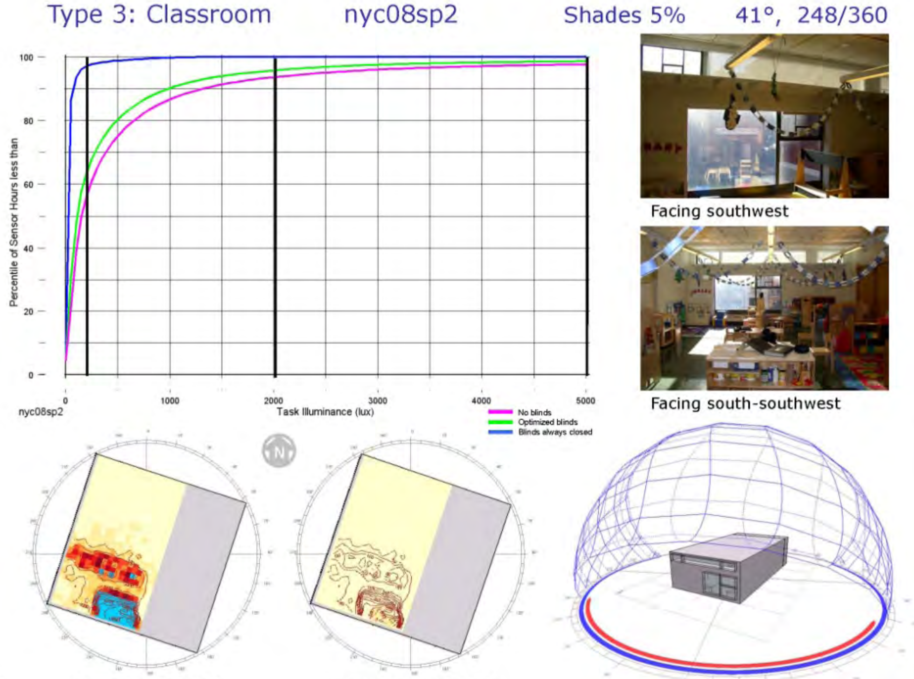


Facing southwest

Facing north

9 Jan. noon no blinds Jan. noon with blinds

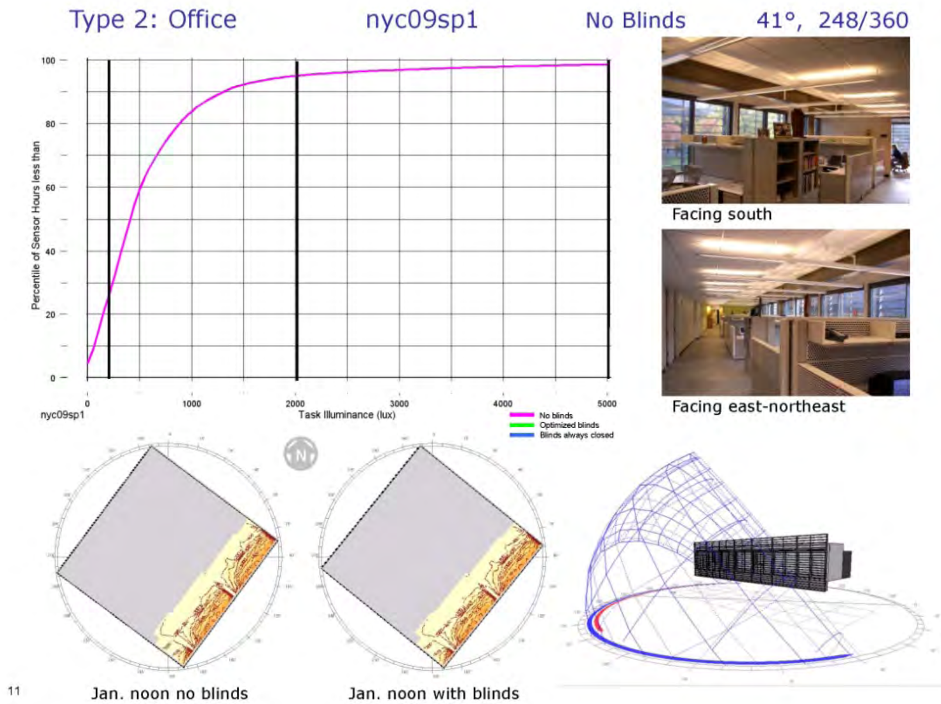
Type 3: Classroom nyc08sp2 Shades 5% 41°, 248/360



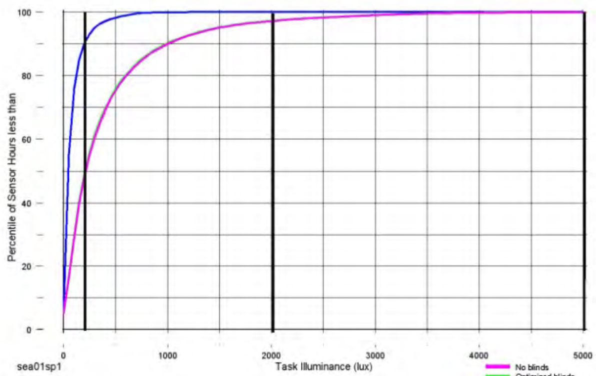
Facing southwest

Facing south-southwest

10 Jan. noon no blinds Jan. noon with blinds

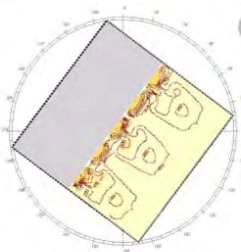

Type 2: Office
nyc09sp1
No Blinds
41°, 248/360
Percentile of Sensor Hours less than
100
80
60
40
20
0
0
1000
2000
3000
4000
5000
nyc09sp1
Task Illuminance (lux)
No blinds
Optimized blinds
Blinds always closed
Facing south
Facing east-northeast
11
Jan. noon no blinds
Jan. noon with blinds

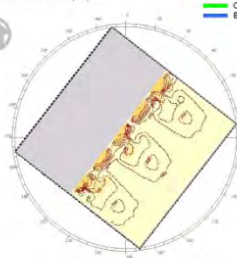
Type 2: Office sea01sp1 N/A 48°, 103/490

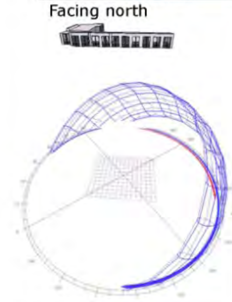


Facing northwest

Facing north

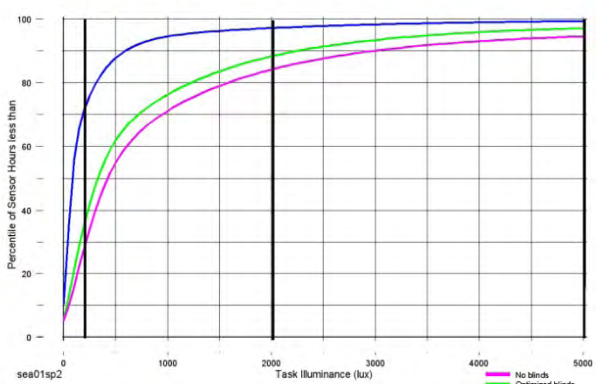






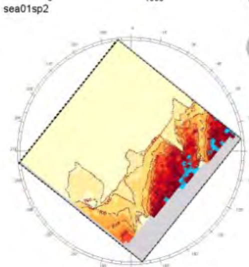
12 Jan. noon no blinds Jan. noon with blinds

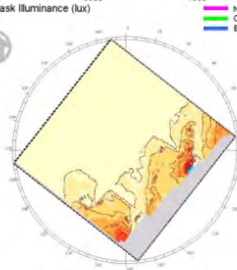
Type 2: Office sea01sp2 Blinds 20% 48°, 103/490

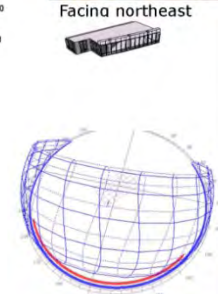


Facing south

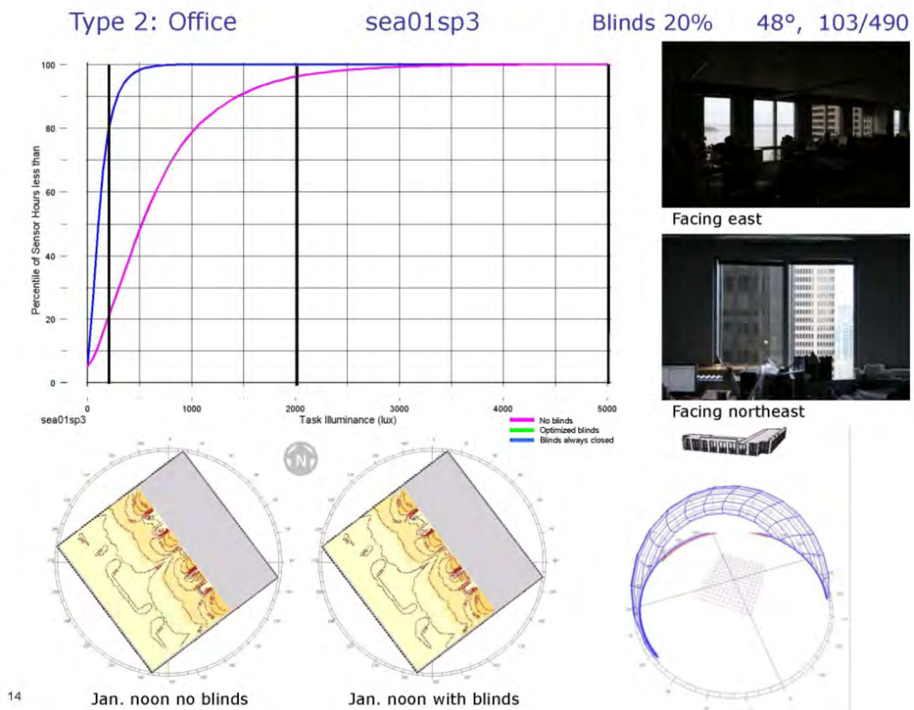
Facing northeast

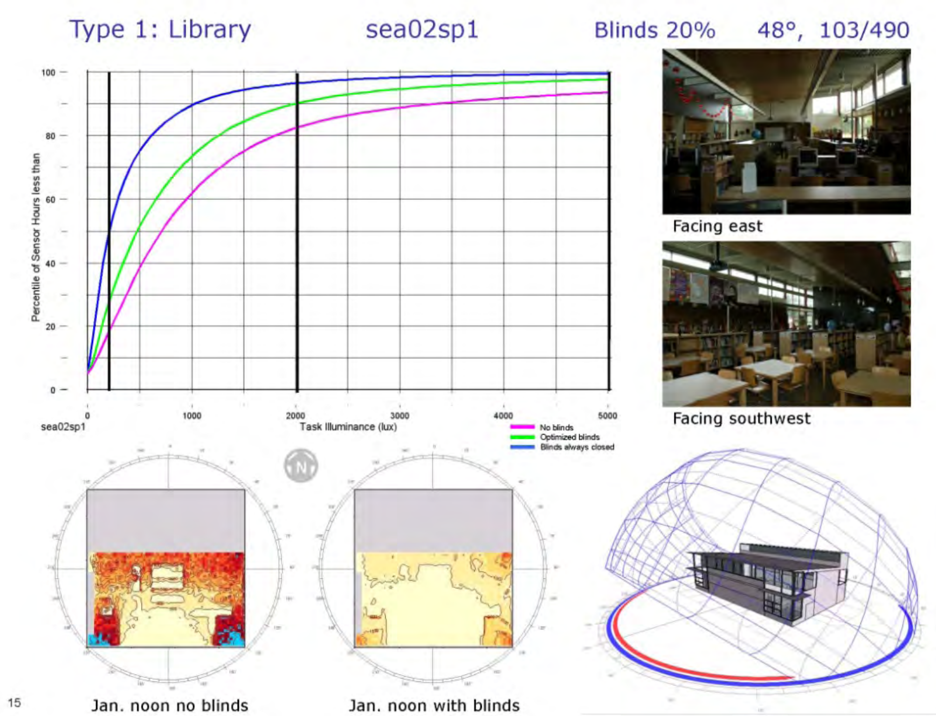




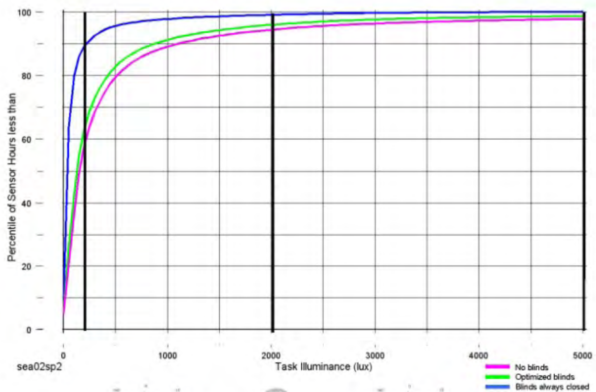


13 Jan. noon no blinds Jan. noon with blinds


Type 2: Office
sea01sp3
Blinds 20%
48°, 103/490
Percentile of Sensor Hours less than
Task Illuminance (lux)
sea01sp3
No blinds
Optimized blinds
Blinds always closed
Facing east
Facing northeast
Jan. noon no blinds
Jan. noon with blinds
14

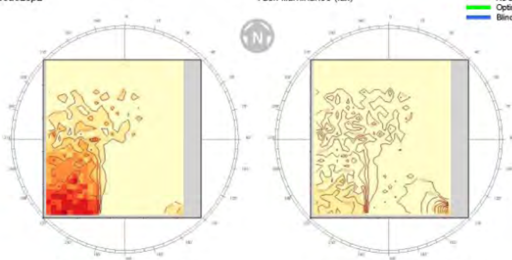

Type 1: Library
sea02sp1
Blinds 20%
48°, 103/490
Percentile of Sensor Hours less than
Task Illuminance (lux)
sea02sp1
No blinds
Optimized blinds
Blinds always closed
Facing east
Facing southwest
Jan. noon no blinds
Jan. noon with blinds
15

Type 3: Classroom sea02sp2 Blinds 20% 48°, 103/490

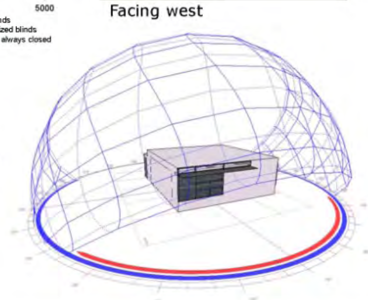


Facing southeast

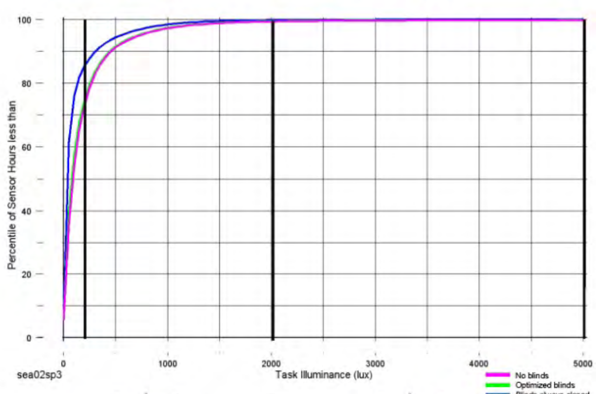
Facing west



16 Jan. noon no blinds Jan. noon with blinds

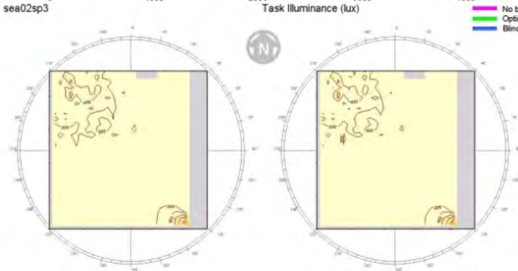


Type 3: Classroom sea02sp3 Blinds 20% 48°, 103/490

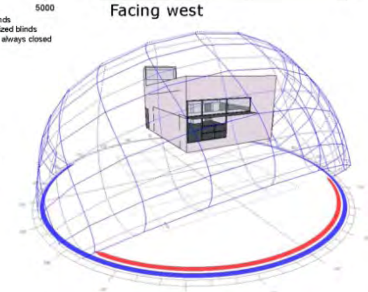


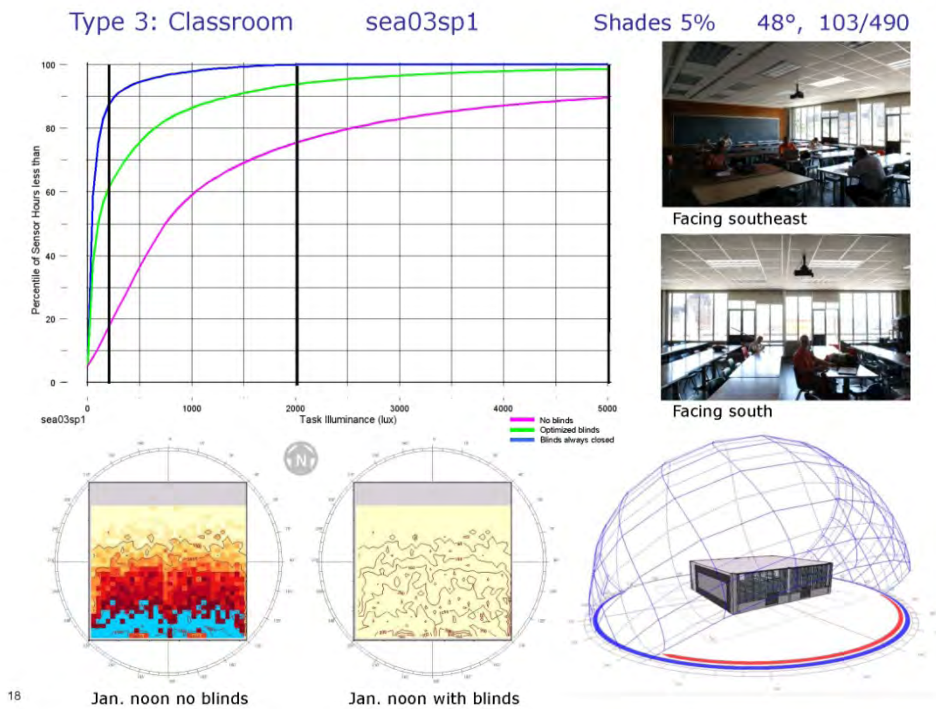
Facing southwest

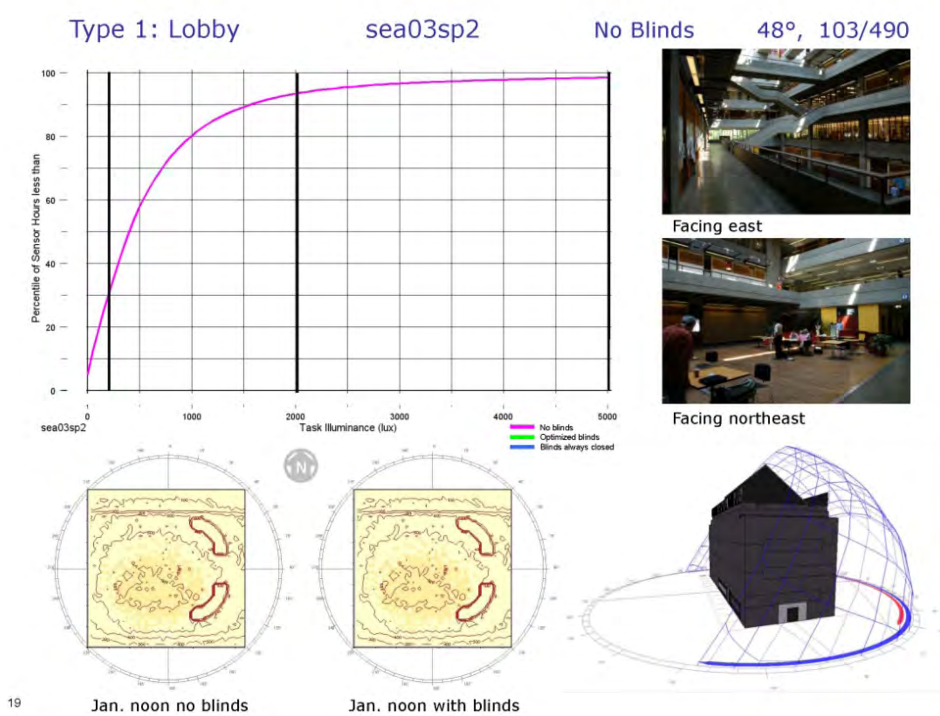
Facing west



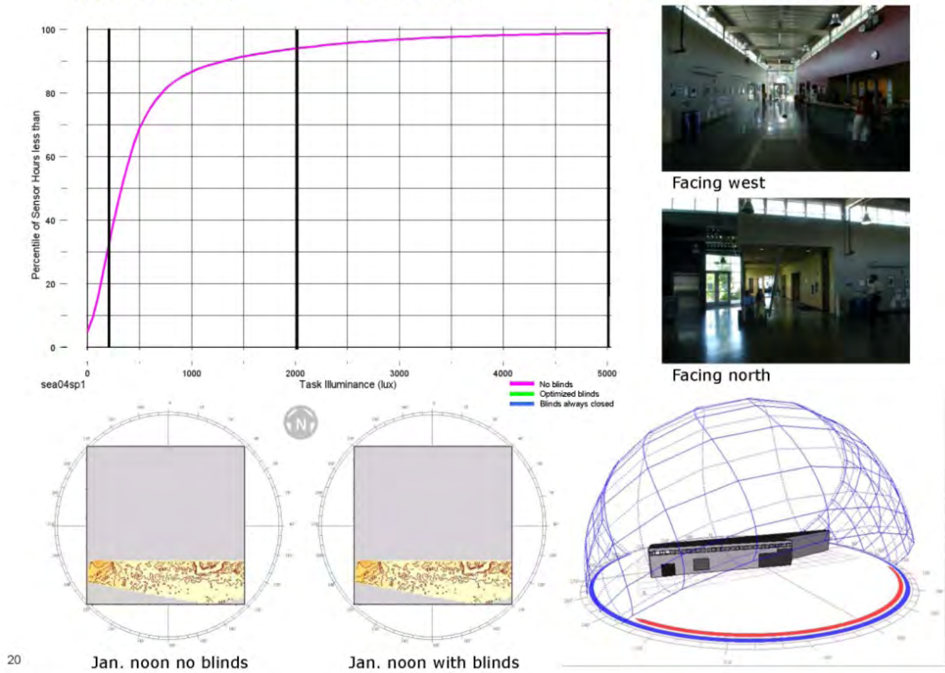
17 Jan. noon no blinds Jan. noon with blinds



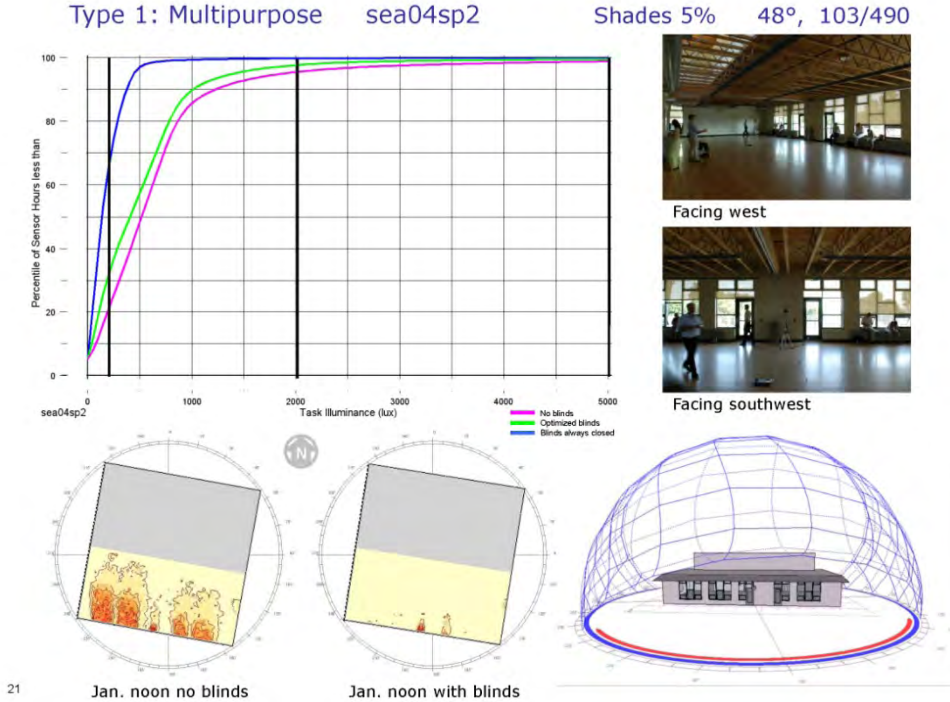

Type 3: Classroom
sea03sp1
Shades 5%
48°, 103/490
Percentile of Sensor Hours less than
Task Illuminance (lux)
sea03sp1
No blinds
Optimized blinds
Blinds always closed
Facing southeast
Facing south
18
Jan. noon no blinds
Jan. noon with blinds


Type 1: Lobby
sea03sp2
No Blinds
48°, 103/490
Percentile of Sensor Hours less than
Task Illuminance (lux)
sea03sp2
No blinds
Optimized blinds
Blinds always closed
Facing east
Facing northeast
19
Jan. noon no blinds
Jan. noon with blinds

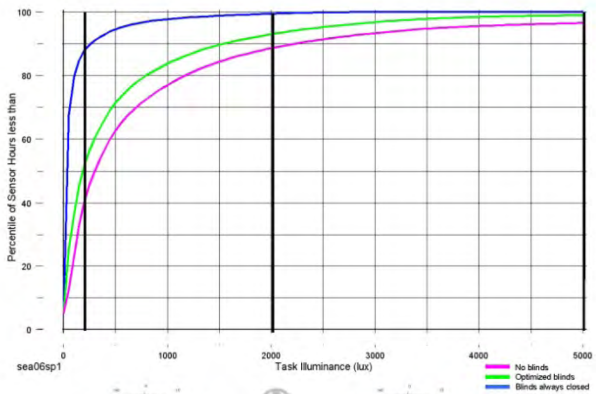
Type 1: Lobby sea04sp1 No Blinds 48°, 103/490



Type 1: Multipurpose sea04sp2 Shades 5% 48°, 103/490

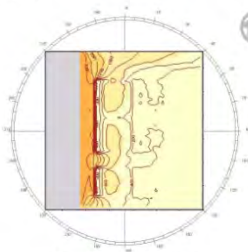


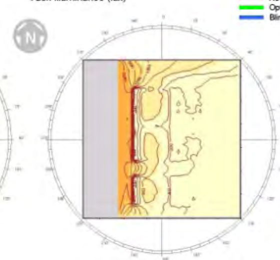
Type 2: Office sea06sp1 Shades 5% 48°, 103/490

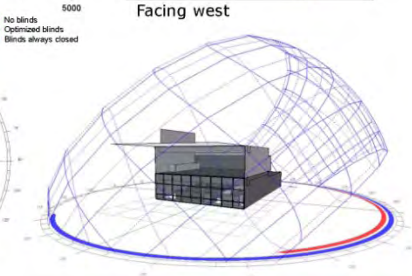


Facing northwest

Facing west

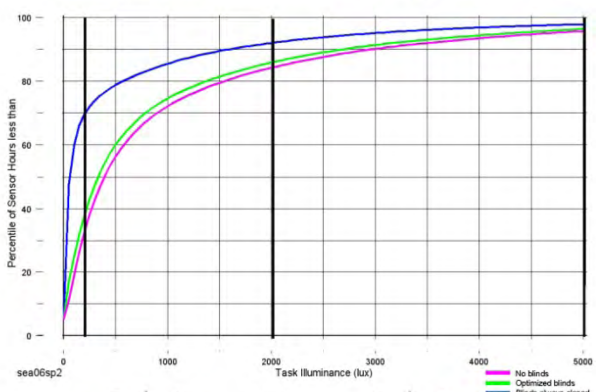






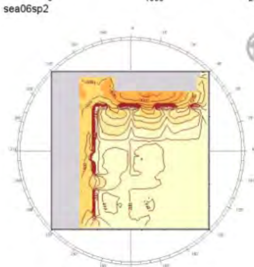
22 Jan. noon no blinds Jan. noon with blinds

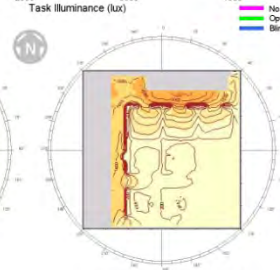
Type 2: Office sea06sp2 Shades 5% 48°, 103/490

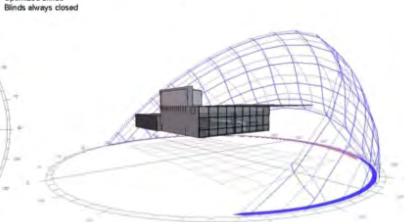


Facing west

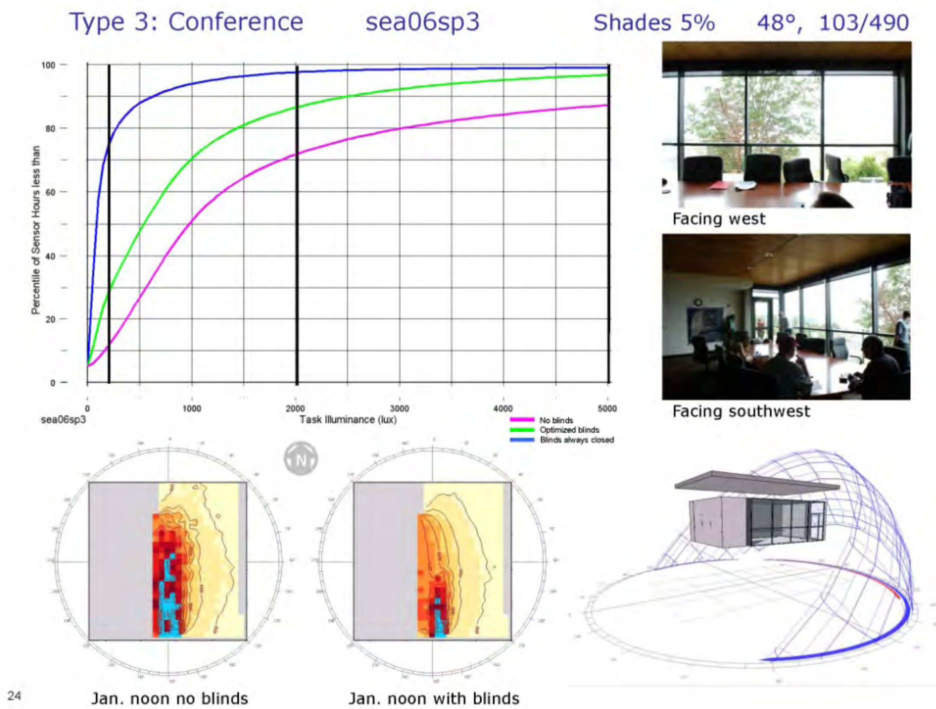
Facing southwest



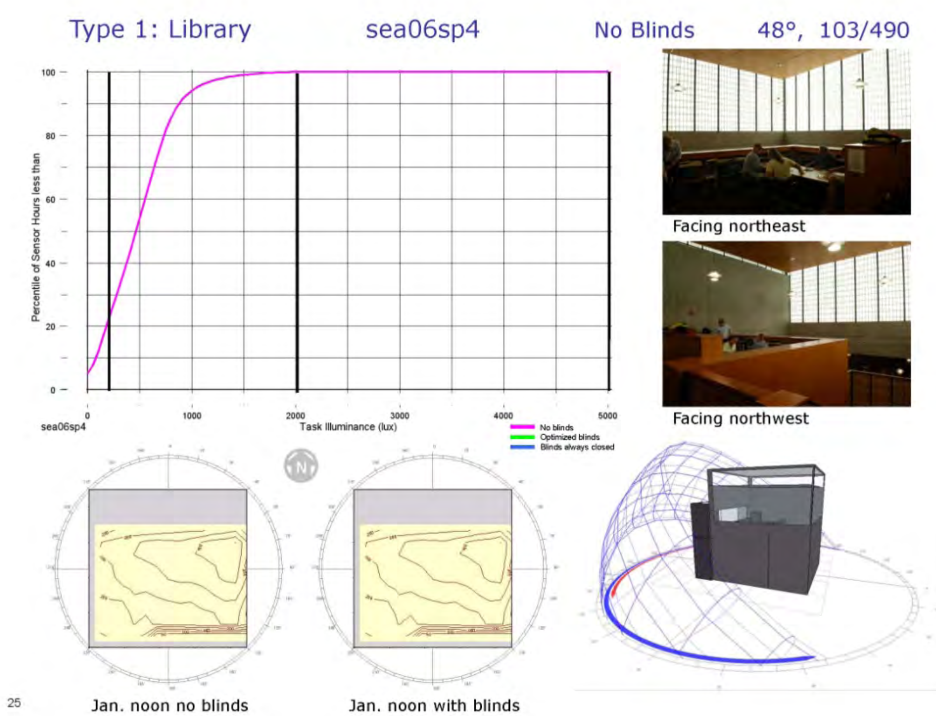




23 Jan. noon no blinds Jan. noon with blinds

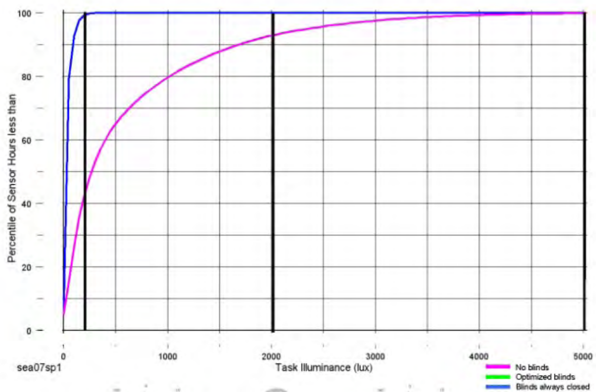


Type 3: Conference
sea06sp3
Shades 5%
48°, 103/490
Percentile of Sensor Hours less than
Task Illuminance (lux)
sea06sp3
No blinds
Optimized blinds
Blinds always closed
Facing west
Facing southwest
24
Jan. noon no blinds
Jan. noon with blinds



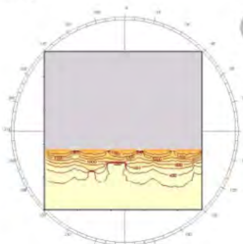
Type 1: Library
sea06sp4
No Blinds
48°, 103/490
Percentile of Sensor Hours less than
Task Illuminance (lux)
sea06sp4
No blinds
Optimized blinds
Blinds always closed
Facing northeast
Facing northwest
25
Jan. noon no blinds
Jan. noon with blinds

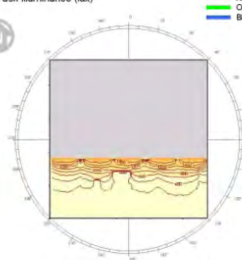
Type 2: Office sea07sp1 Shades 5% 48°, 103/490

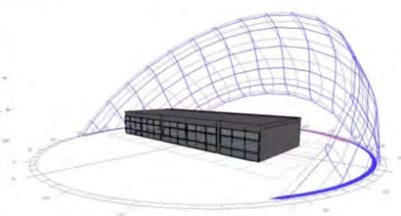


Facing north

Facing west

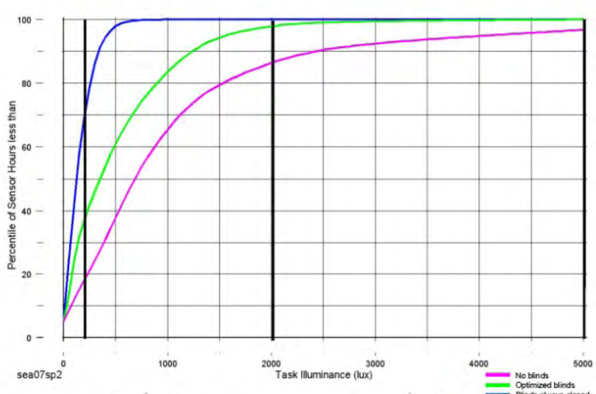


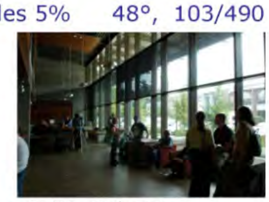




26 Jan. noon no blinds Jan. noon with blinds

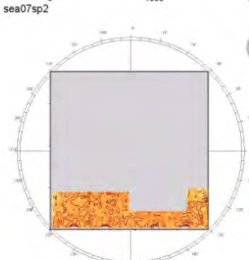
Type 1: Lobby sea07sp2 Shades 5% 48°, 103/490

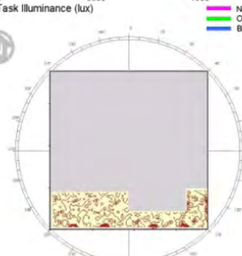


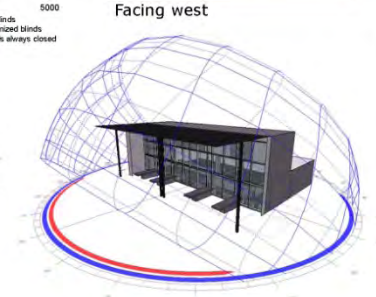


Facing southeast

Facing west

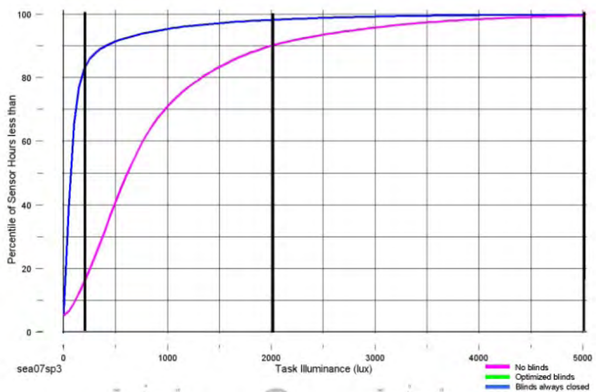






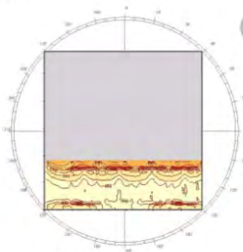
27 Jan. noon no blinds Jan. noon with blinds

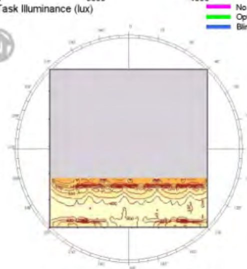
Type 2: Office   sea07sp3   Shades 5%   48°, 103/490

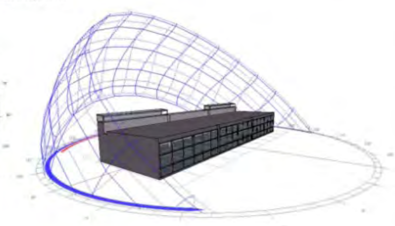


Facing west

Facing northeast



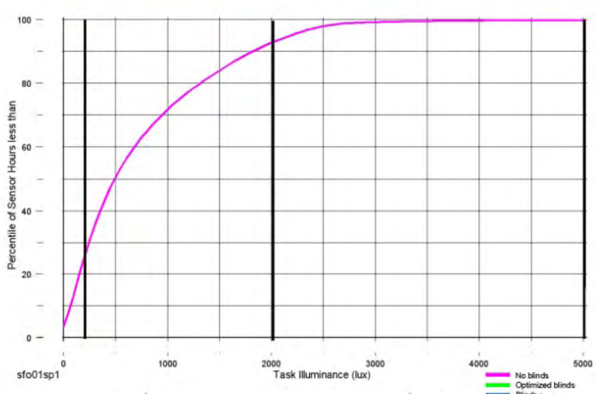




28

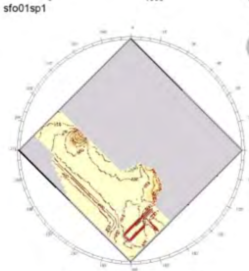
Jan. noon no blinds   Jan. noon with blinds

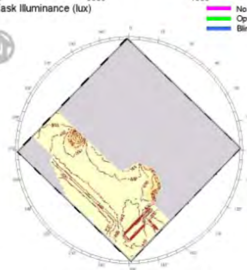
Type 1: Library   sfo01sp1   No Blinds   38°, 274/627

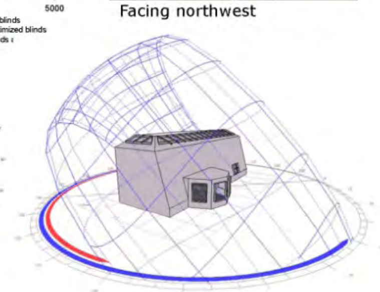


Facing southeast

Facing northwest



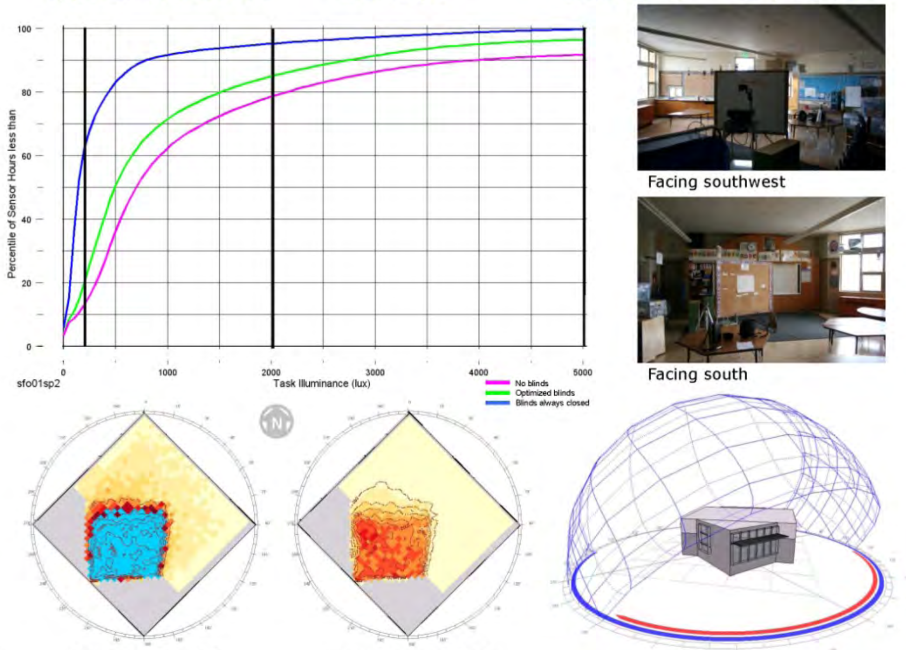




29

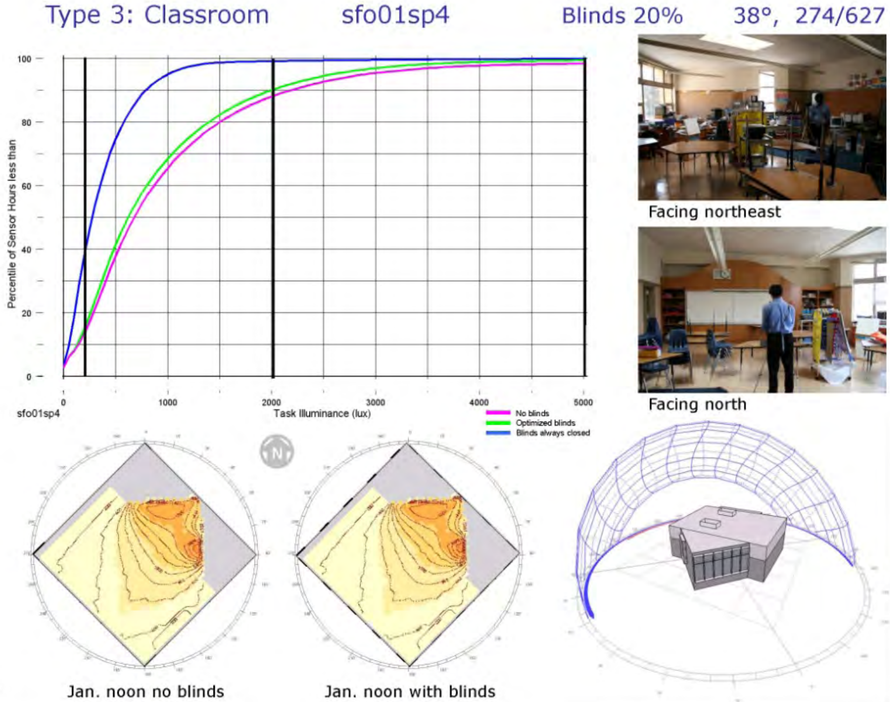
Jan. noon no blinds   Jan. noon with blinds

Type 3: Classroom sfo01sp2 Blinds 20% 38°, 274/627



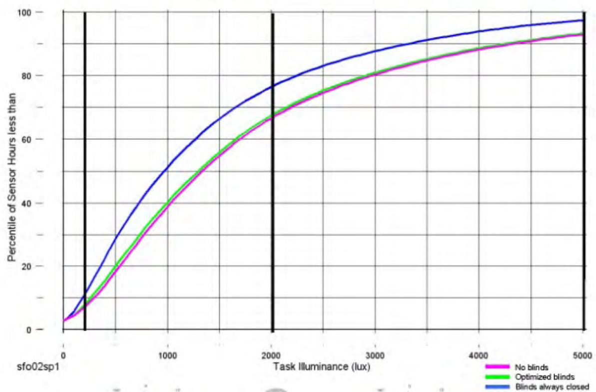
30 Jan. noon no blinds Jan. noon with blinds

Type 3: Classroom sfo01sp4 Blinds 20% 38°, 274/627



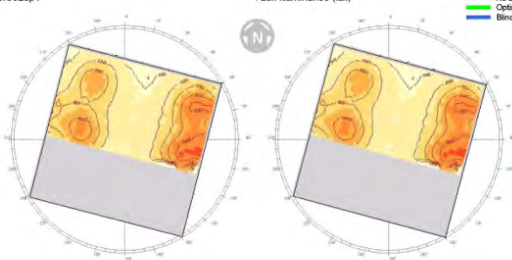
31 Jan. noon no blinds Jan. noon with blinds

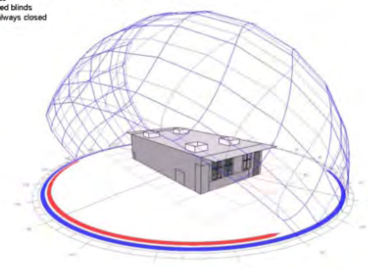
Type 3: Classroom sfo02sp1 Blinds 20% 38°, 274/627



Facing southeast

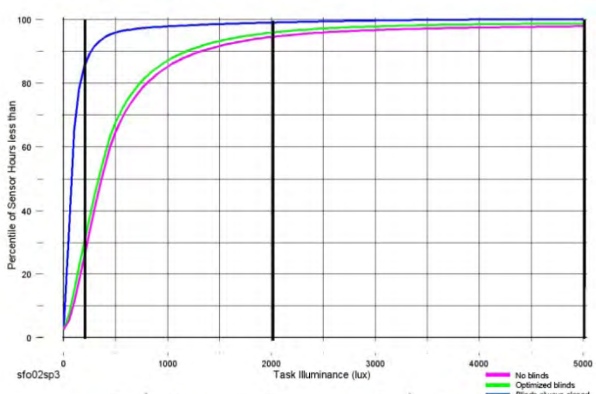
Facing west





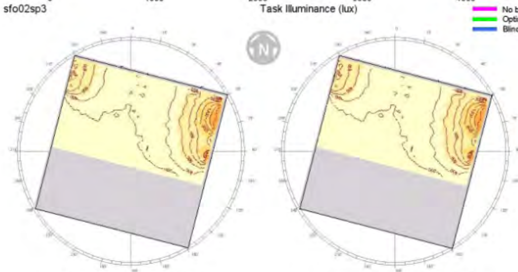
32 Jan. noon no blinds Jan. noon with blinds

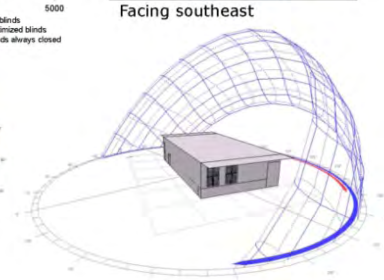
Type 3: Classroom sfo02sp3 Blinds 20% 38°, 274/627



Facing northwest

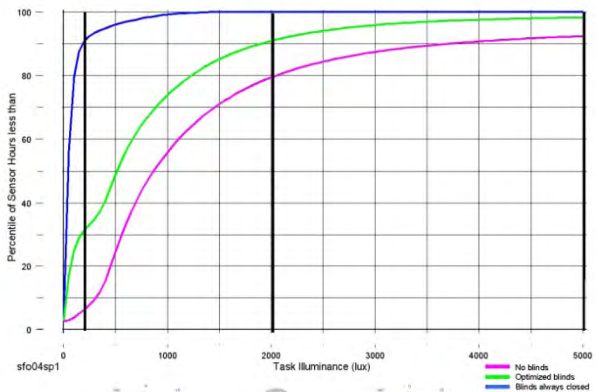
Facing southeast





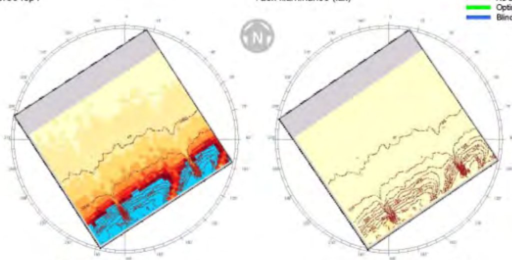
33 Jan. noon no blinds Jan. noon with blinds

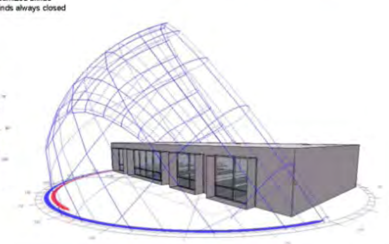
Type 2: Office   sfo04sp1   Shades 5%   38°, 303/672



Facing southeast

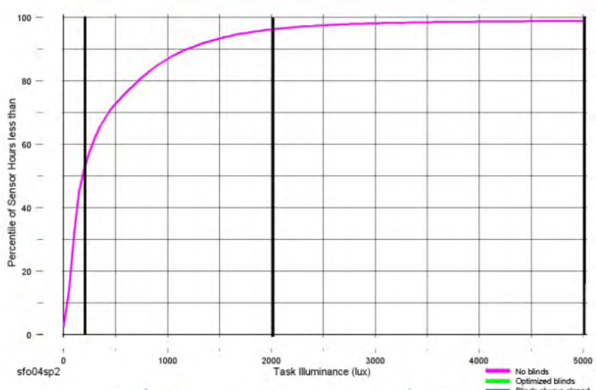
Facing southeast

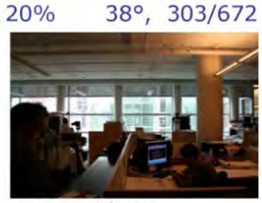




34 Jan. noon no blinds   Jan. noon with blinds

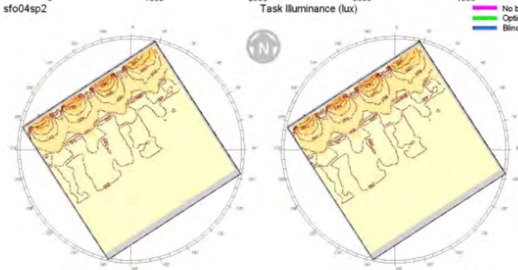
Type 2: Office   sfo04sp2   Blinds 20%   38°, 303/672

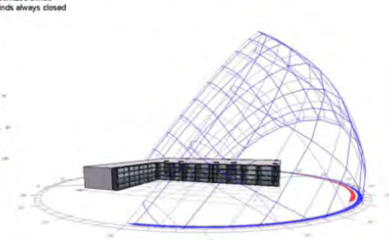




Facing northwest

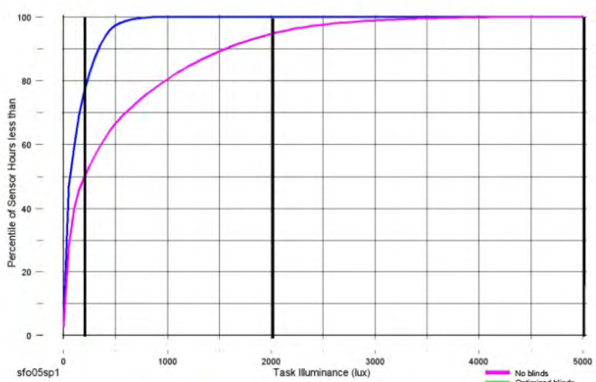
Facing north





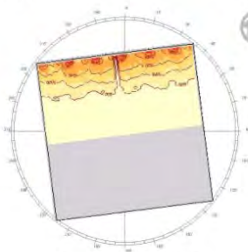
35 Jan. noon no blinds   Jan. noon with blinds

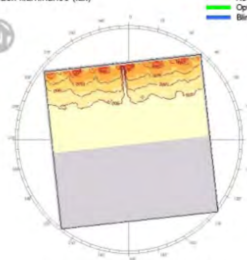
Type 2: Office sfo05sp1 Blinds 20% 38°, 303/672

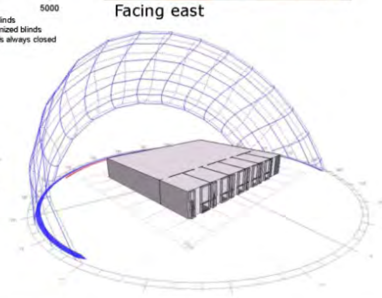


Facing northwest

Facing east

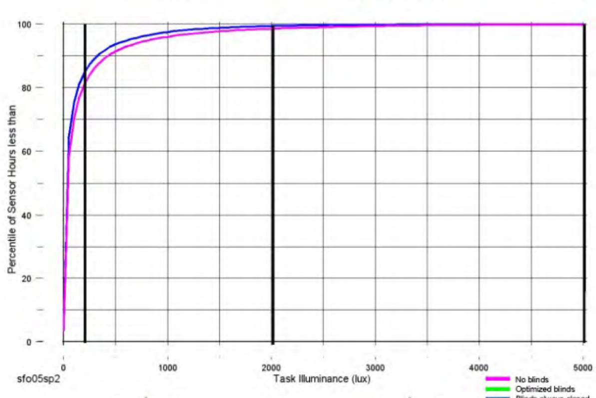






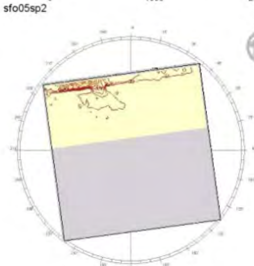
36 Jan. noon no blinds Jan. noon with blinds

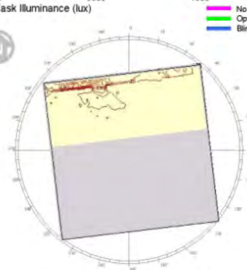
Type 2: Office sfo05sp2 Blinds 20% 38°, 303/672

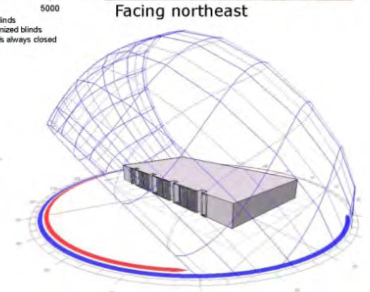


Facing west

Facing northeast

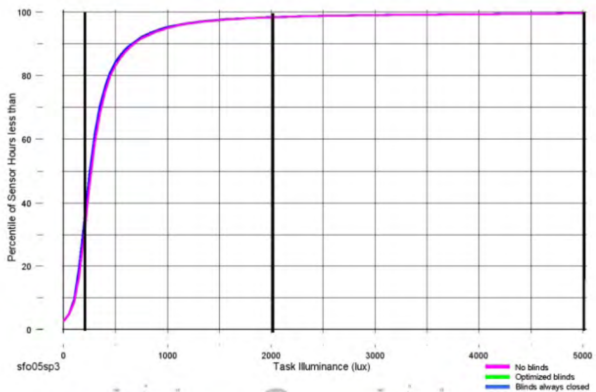






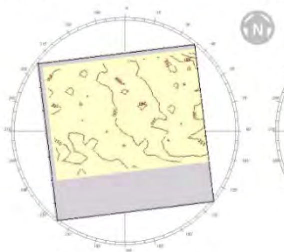
37 Jan. noon no blinds Jan. noon with blinds

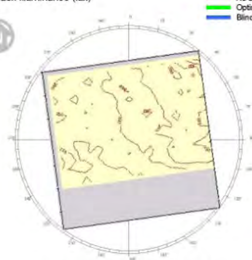
Type 3: Conference sfo05sp3 No Blinds 38°, 303/672

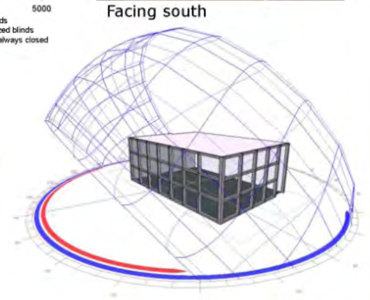


Facing southeast

Facing south

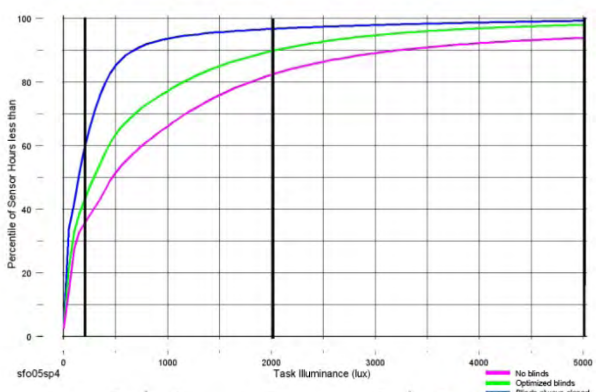


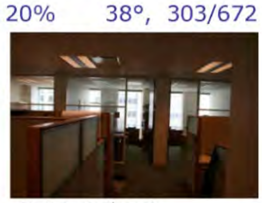




38 Jan. noon no blinds Jan. noon with blinds

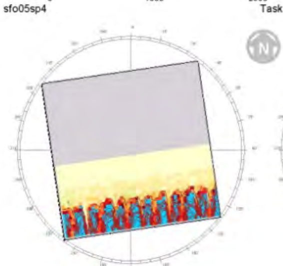
Type 3: Conference sfo05sp4 Blinds 20% 38°, 303/672

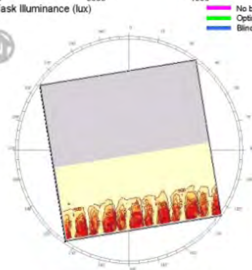


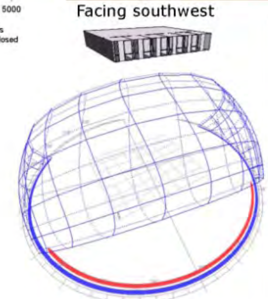


Facing southeast

Facing southwest

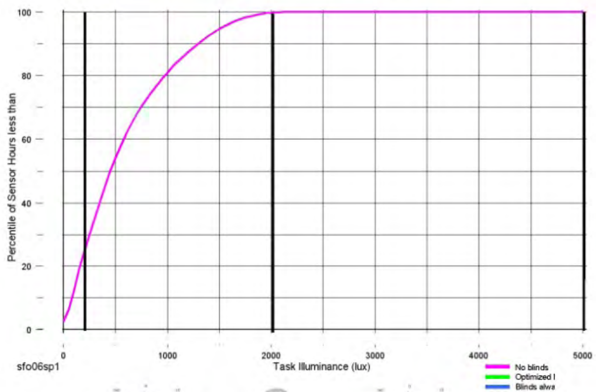






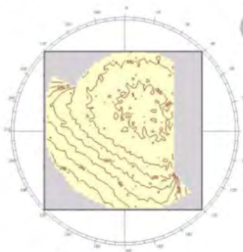
39 Jan. noon no blinds Jan. noon with blinds

Type 1: Lobby sfo06sp1 No Blinds 38°, 303/672

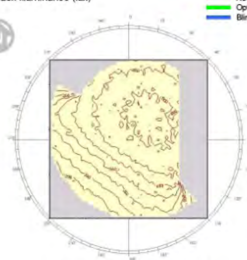


Facing east

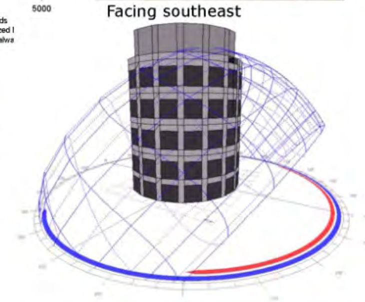
Facing southeast



Jan. noon no blinds

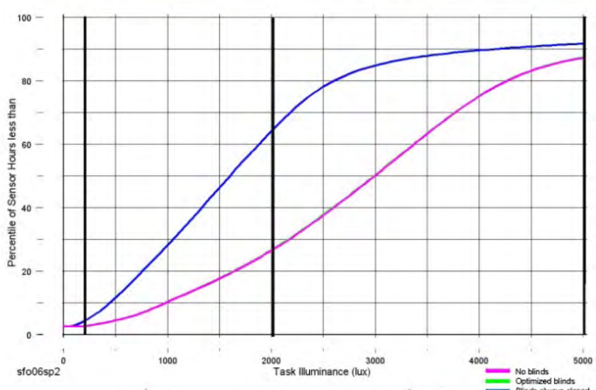


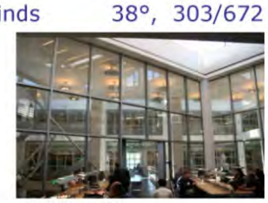
Jan. noon with blinds



40

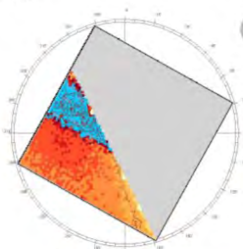
Type 1: Library sfo06sp2 No Blinds 38°, 303/672



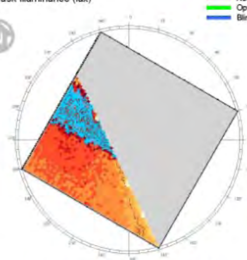


Facing west

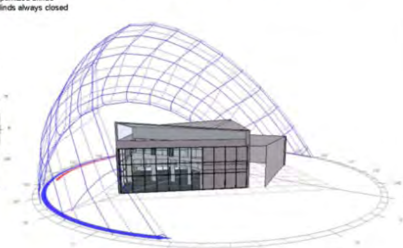
Facing south and upwards



Jan. noon no blinds

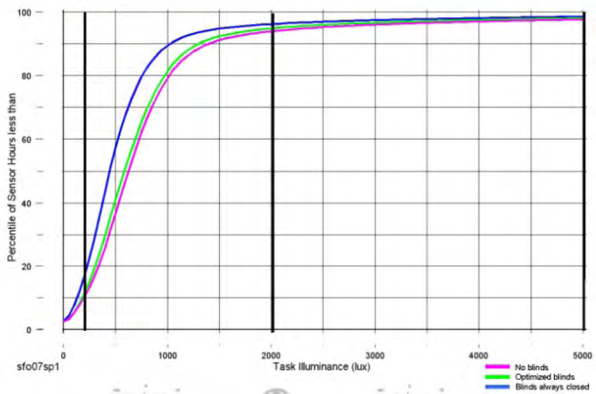


Jan. noon with blinds



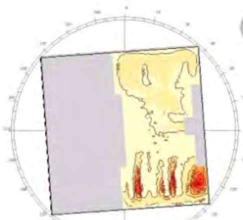
41

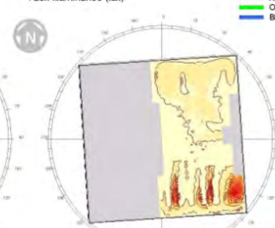
Type 1: Library sfo07sp1 Shades 5% 38°, 303/672

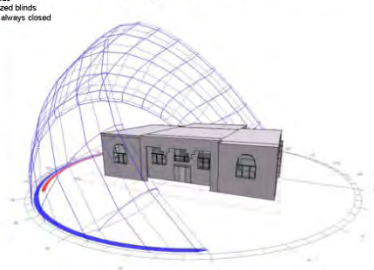


Facing southeast

Facing northeast

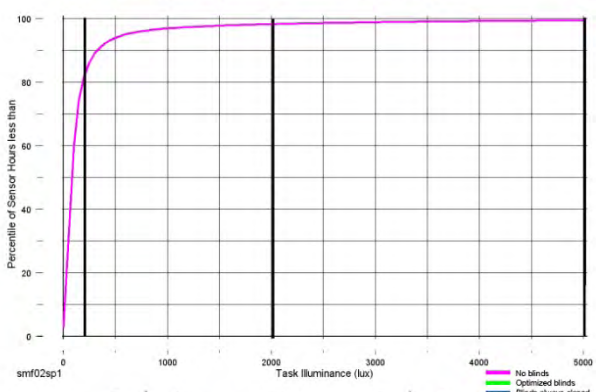






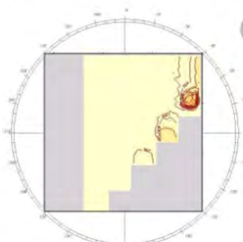
42 Jan. noon no blinds Jan. noon with blinds

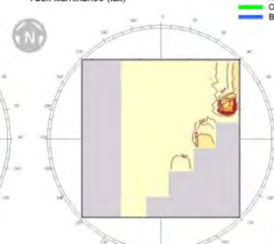
Type 1: Library smf02sp1 No Blinds 39°, 170/743

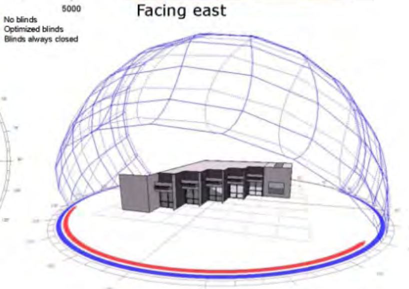


Facing southwest

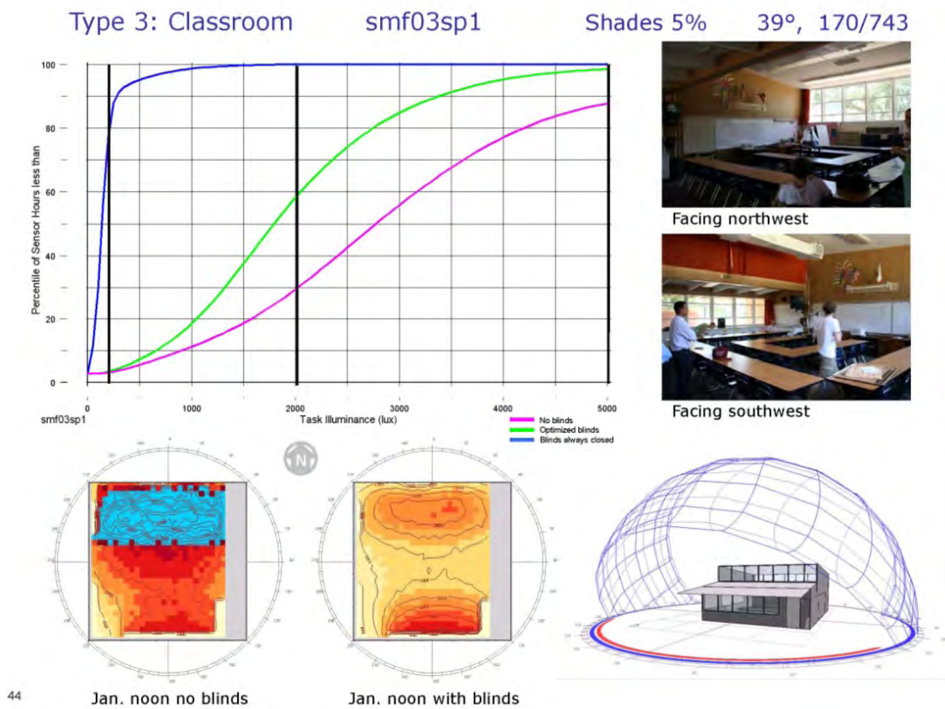
Facing east

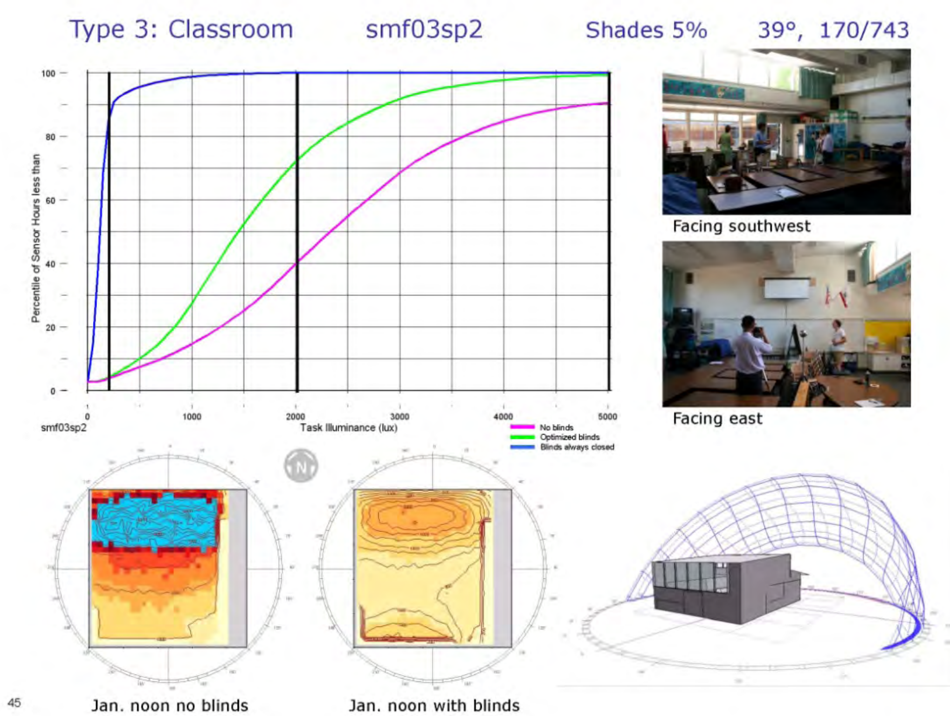




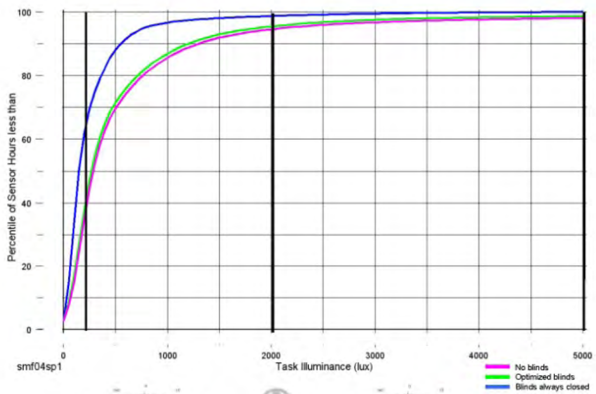


43 Jan. noon no blinds Jan. noon with blinds


Type 3: Classroom smf03sp1 Shades 5% 39°, 170/743
Percentile of Sensor Hours less than
Task Illuminance (lux)
smf03sp1
No blinds
Optimized blinds
Blinds always closed
Facing northwest
Facing southwest
44
Jan. noon no blinds
Jan. noon with blinds

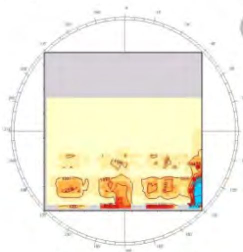

Type 3: Classroom smf03sp2 Shades 5% 39°, 170/743
Percentile of Sensor Hours less than
Task Illuminance (lux)
smf03sp2
No blinds
Optimized blinds
Blinds always closed
Facing southwest
Facing east
45
Jan. noon no blinds
Jan. noon with blinds

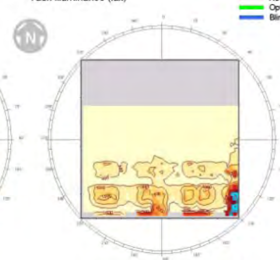
Type 2: Office smf04sp1 Blinds 20% 39°, 170/743

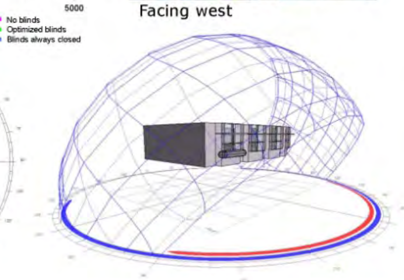


Facing southwest

Facing west

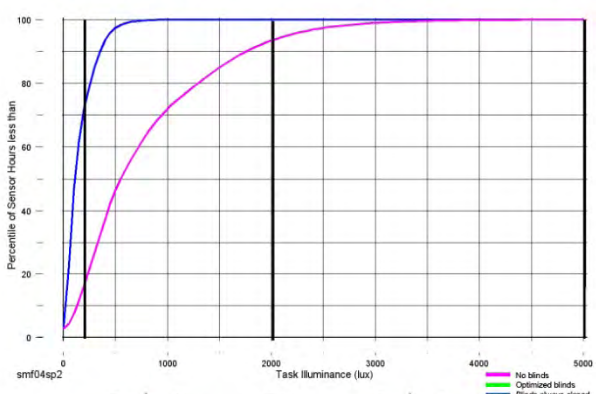


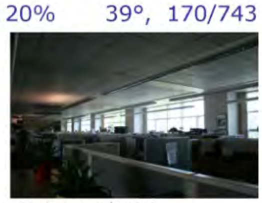




46 Jan. noon no blinds Jan. noon with blinds

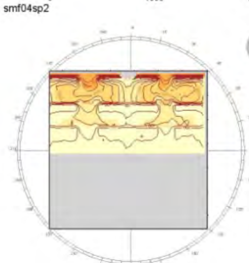
Type 2: Office smf04sp2 Blinds 20% 39°, 170/743

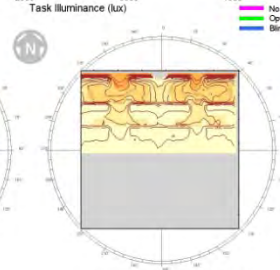


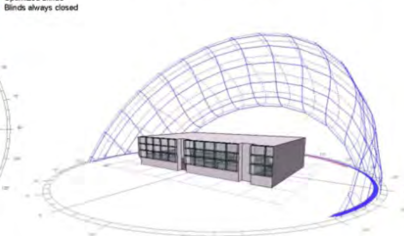


Facing northwest

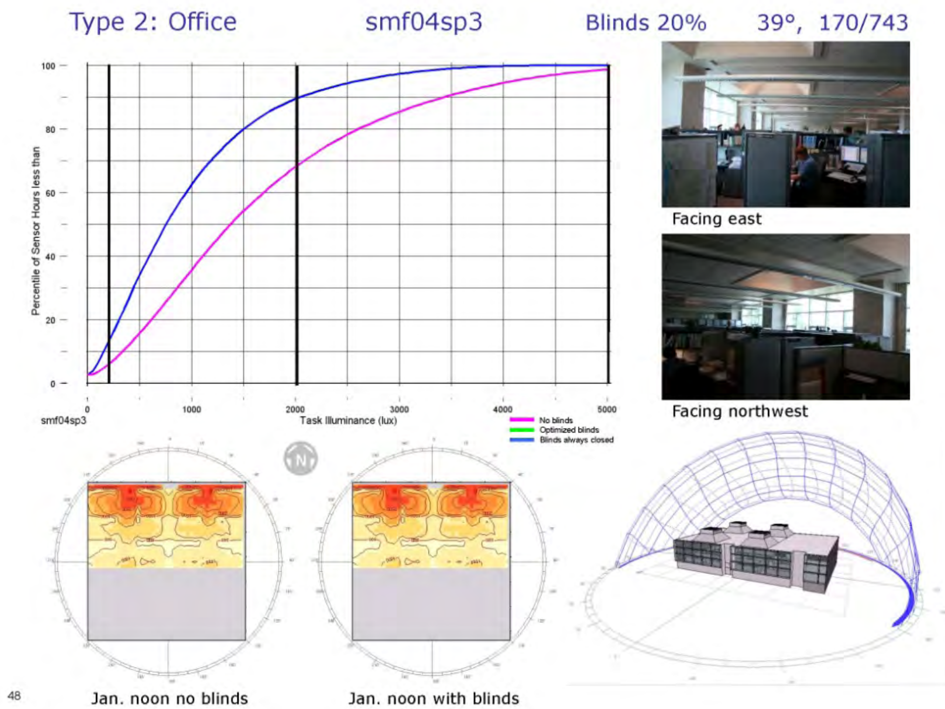
Facing northeast



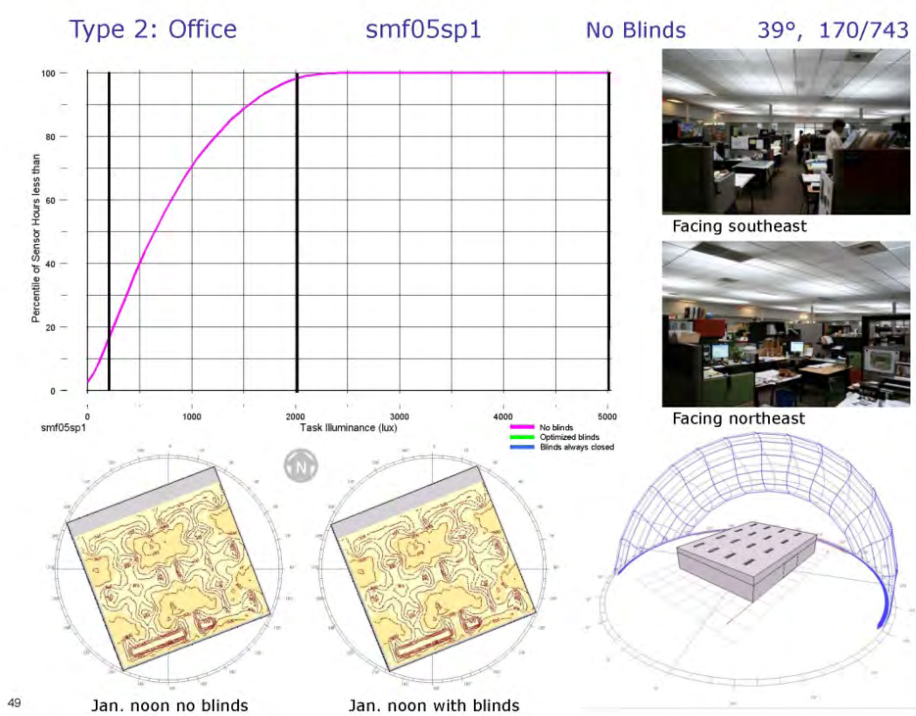




47 Jan. noon no blinds Jan. noon with blinds

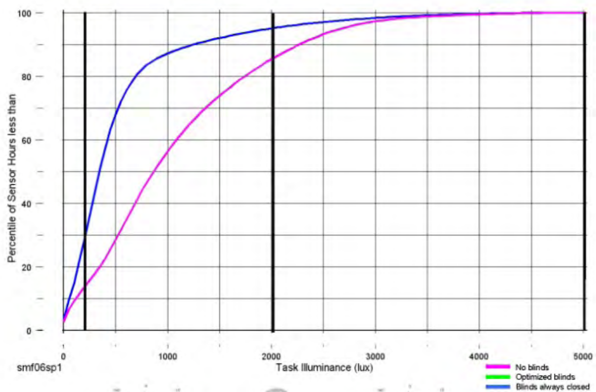


Type 2: Office
smf04sp3
Blinds 20%
39°, 170/743
Percentile of Sensor Hours less than
Task Illuminance (lux)
smf04sp3
No blinds
Optimized blinds
Blinds always closed
Facing east
Facing northwest
48
Jan. noon no blinds
Jan. noon with blinds



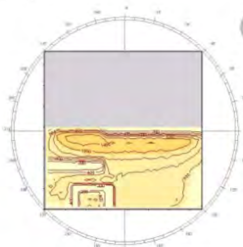
Type 2: Office
smf05sp1
No Blinds
39°, 170/743
Percentile of Sensor Hours less than
Task Illuminance (lux)
smf05sp1
No blinds
Optimized blinds
Blinds always closed
Facing southeast
Facing northeast
49
Jan. noon no blinds
Jan. noon with blinds

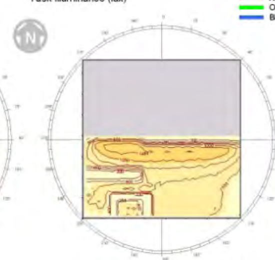
Type 1: Library smf06sp1 Blinds 20% 39°, 170/743

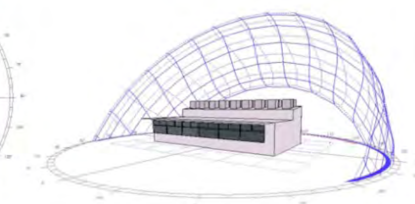


Facing north

Facing west

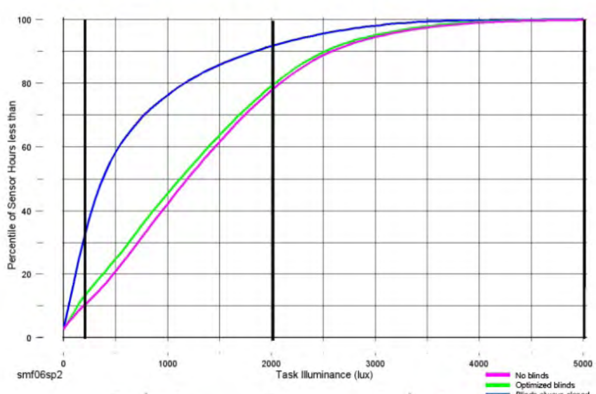






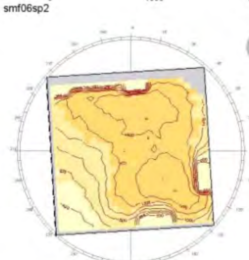
50 Jan. noon no blinds Jan. noon with blinds

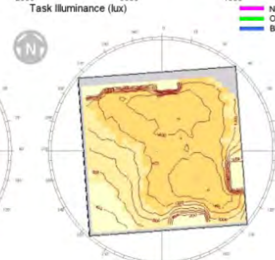
Type 3: Classroom smf06sp2 Shades 5% 39°, 170/743

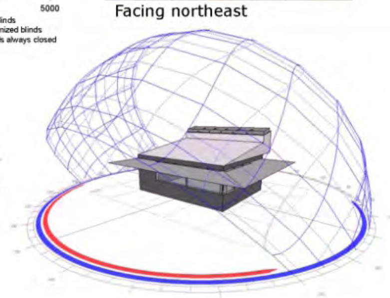


Facing east

Facing northeast

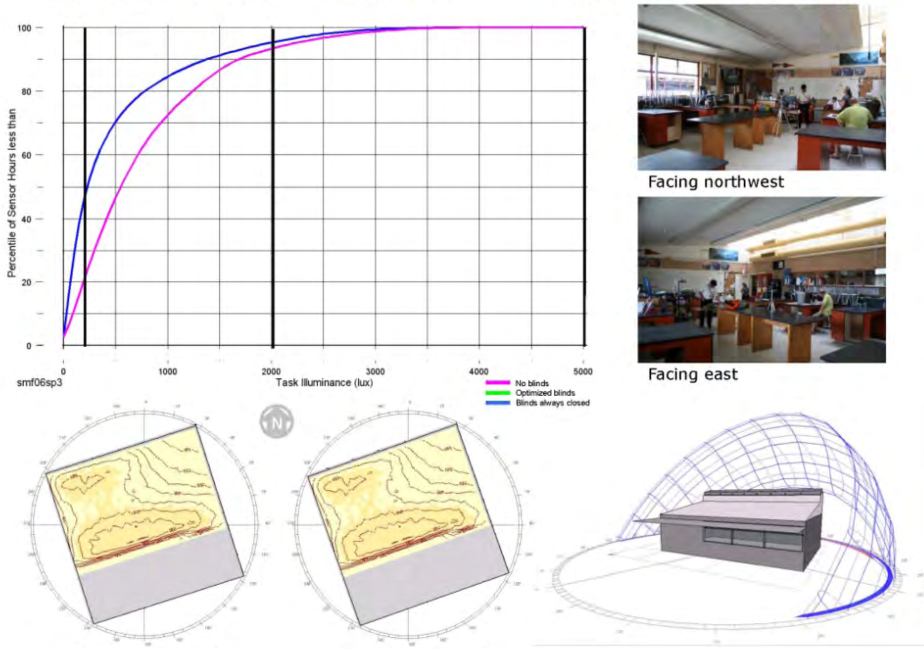






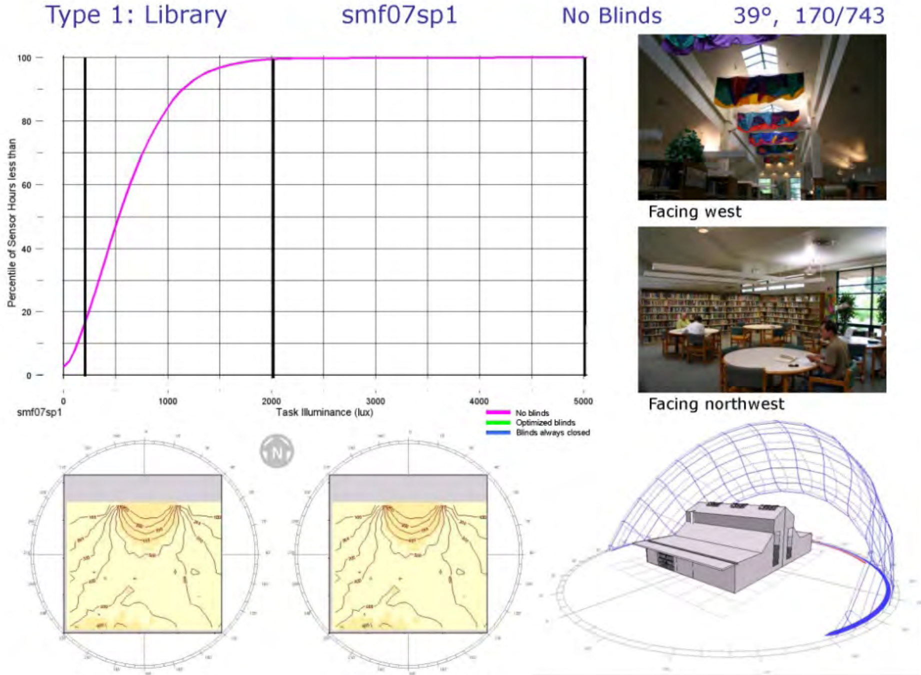
51 Jan. noon no blinds Jan. noon with blinds

Type 3: Classroom smf06sp3 Shades 5% 39°, 170/743

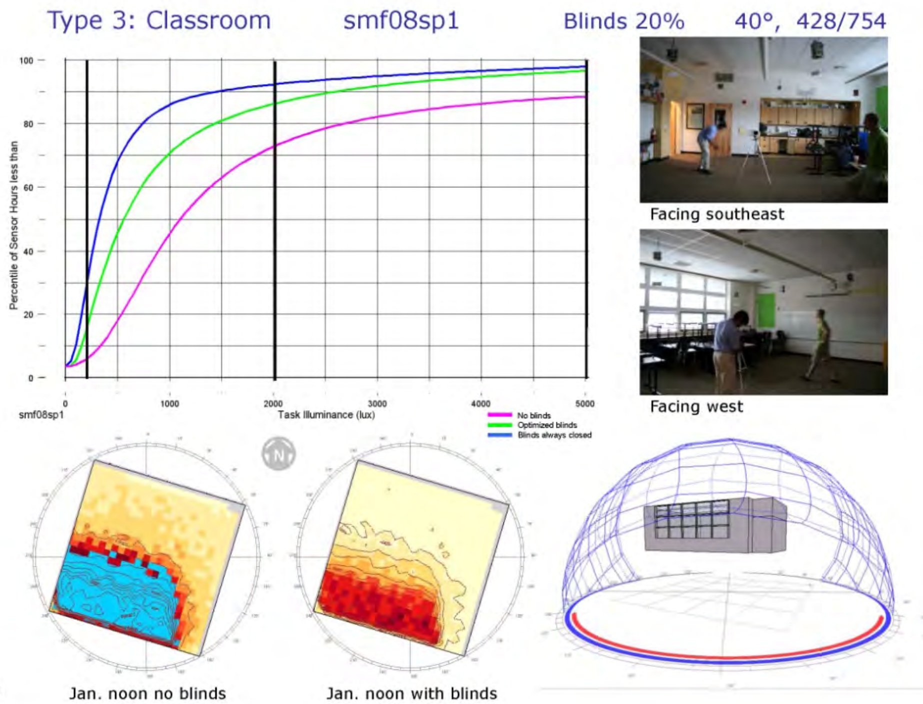


52 Jan. noon no blinds Jan. noon with blinds

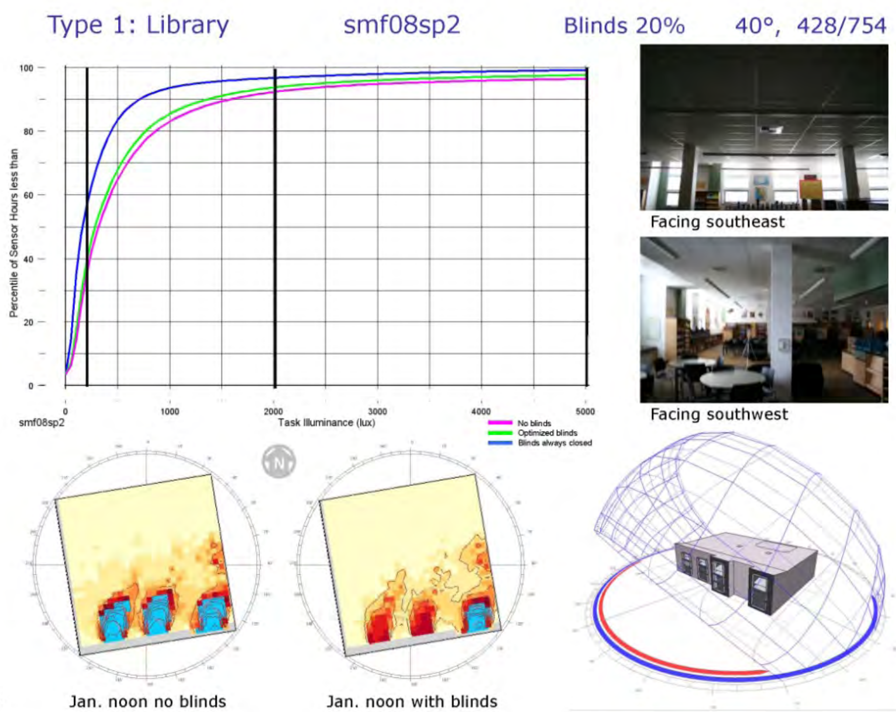
Type 1: Library smf07sp1 No Blinds 39°, 170/743



53 Jan. noon no blinds Jan. noon with blinds

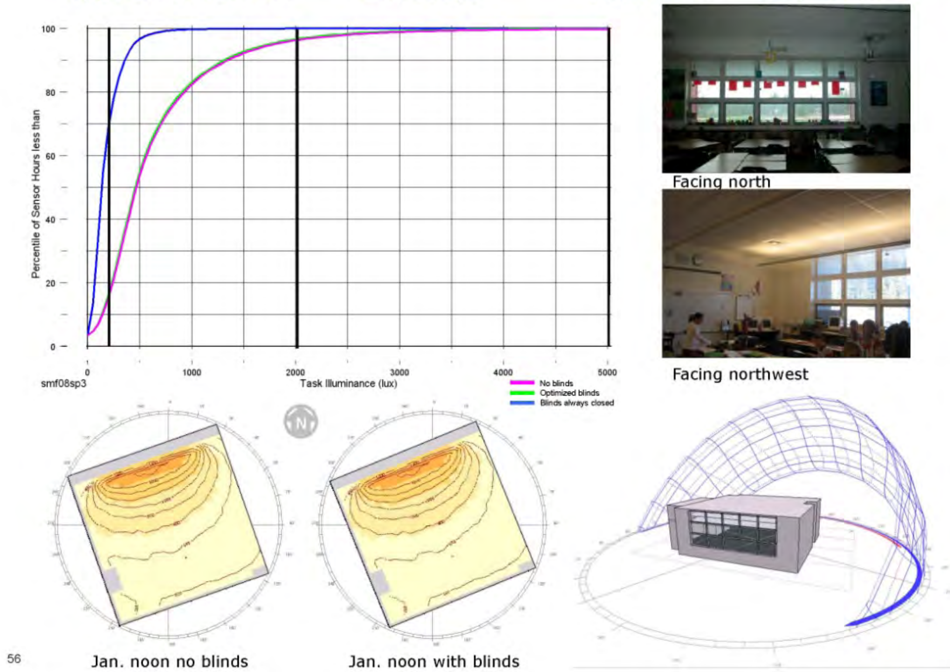

Type 3: Classroom
smf08sp1
Blinds 20%
40°, 428/754
Percentile of Sensor Hours less than
Task Illuminance (lux)
smf08sp1
No blinds
Optimized blinds
Blinds always closed
Facing southeast
Facing west
Jan. noon no blinds
Jan. noon with blinds

54

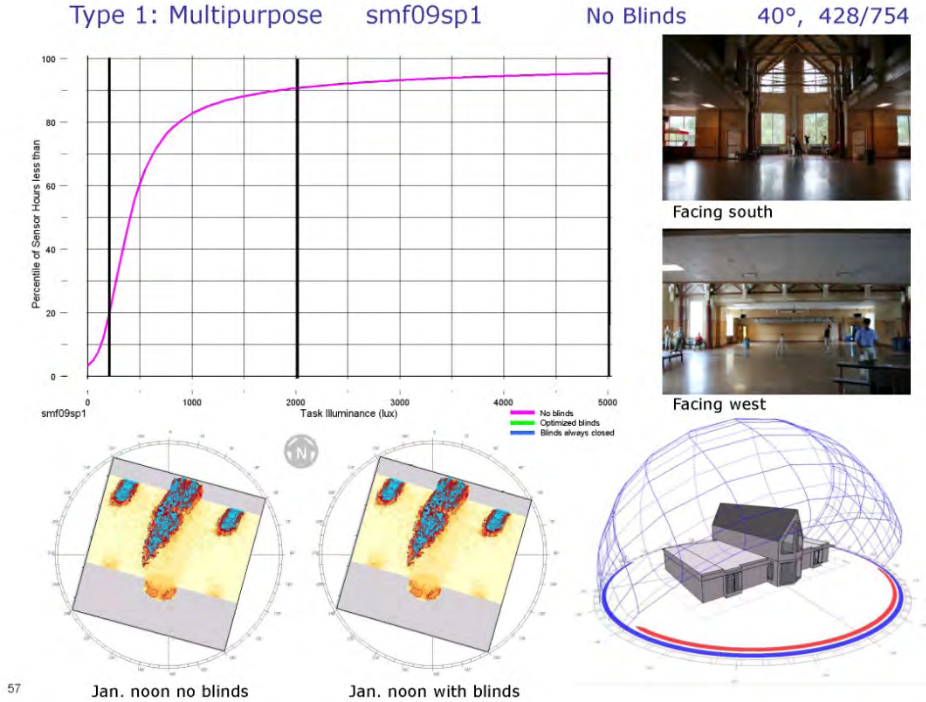

Type 1: Library
smf08sp2
Blinds 20%
40°, 428/754
Percentile of Sensor Hours less than
Task Illuminance (lux)
smf08sp2
No blinds
Optimized blinds
Blinds always closed
Facing southeast
Facing southwest
Jan. noon no blinds
Jan. noon with blinds

55

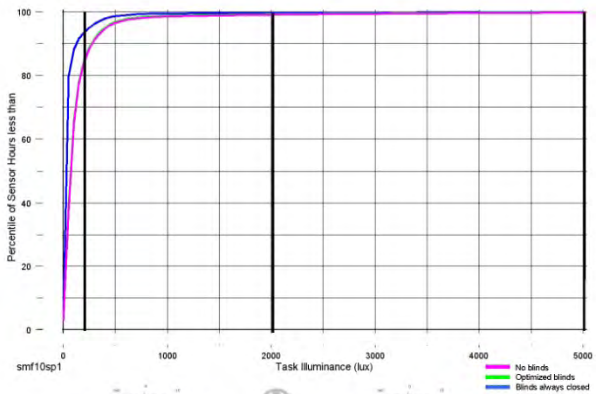
Type 3: Classroom smf08sp3 Blinds 20% 40°, 428/754



Type 1: Multipurpose smf09sp1 No Blinds 40°, 428/754

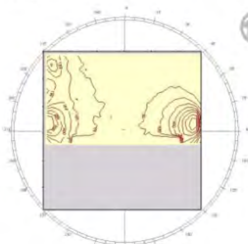


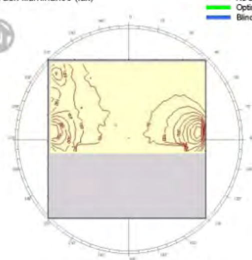
Type 3: Classroom smf10sp1 Shades 5% 39°, 428/754

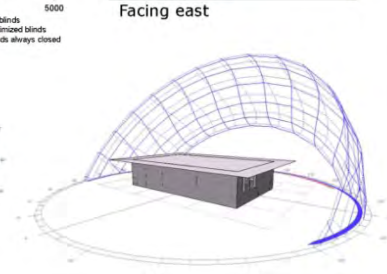


Facing northwest

Facing east

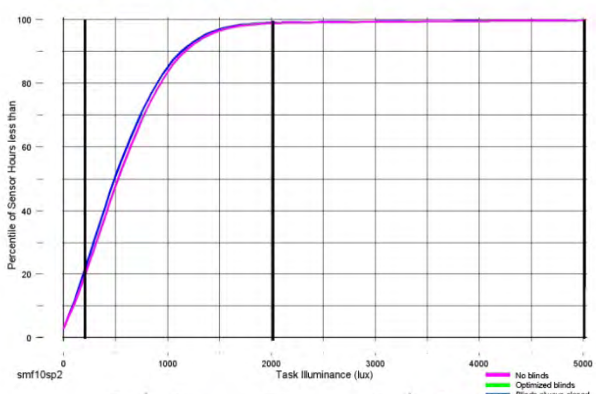






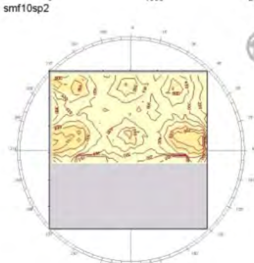
58 Jan. noon no blinds Jan. noon with blinds

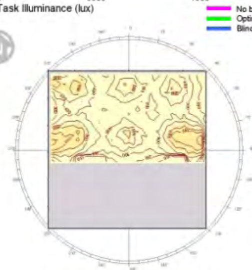
Type 3: Classroom smf10sp2 Shades 5% 39°, 428/754

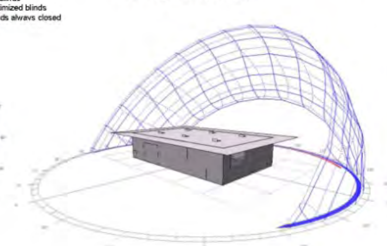


Facing west

Facing southeast

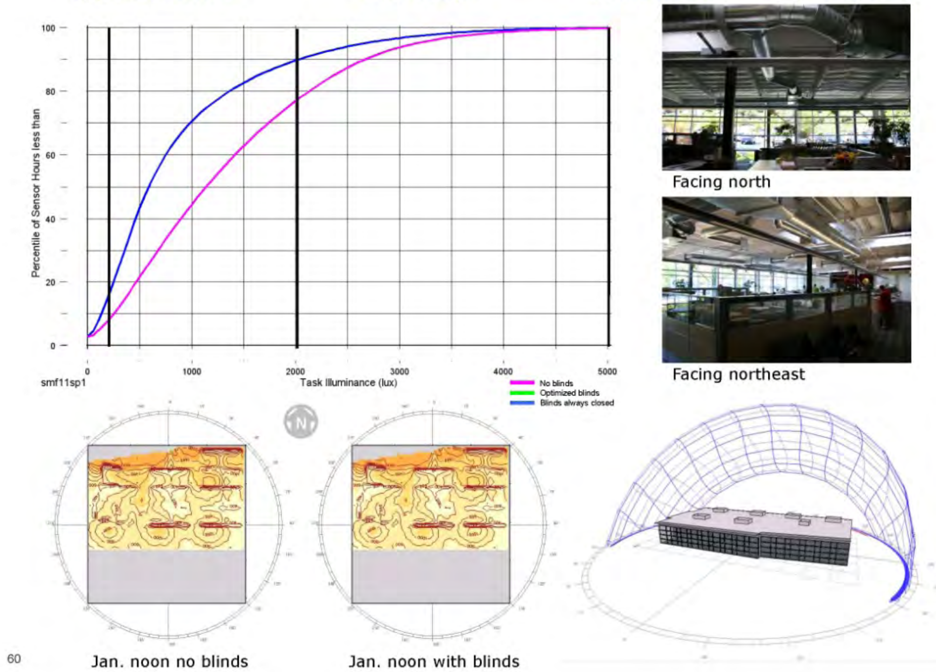




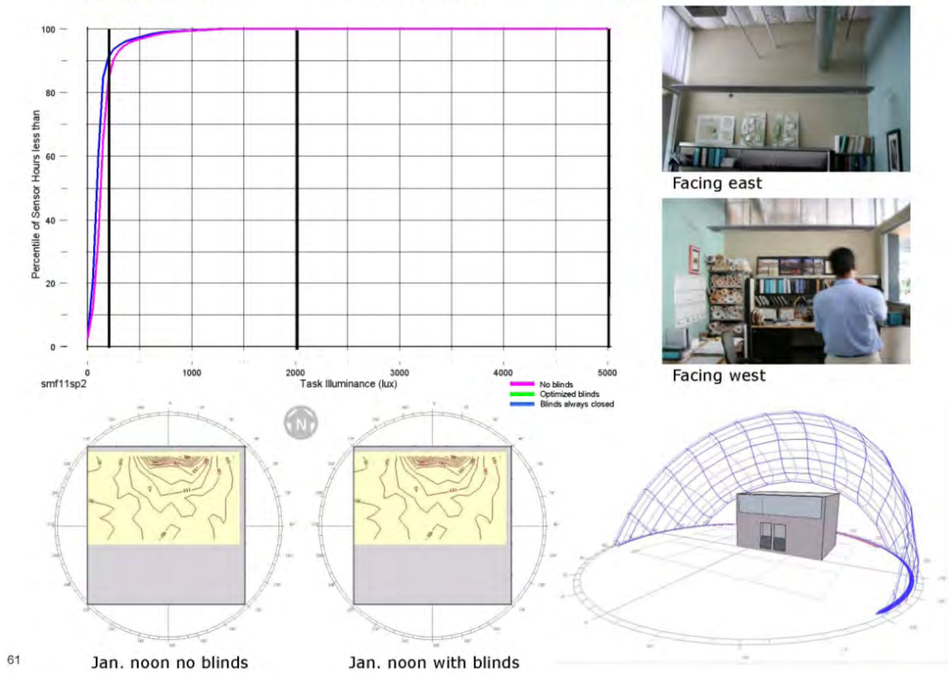


59 Jan. noon no blinds Jan. noon with blinds

Type 2: Office smf11sp1 Blinds 20% 39°, 428/754



Type 2: Office smf11sp2 No Blinds 39°, 428/754



D-3 Spatial Daylight Autonomy Plots

NOTE: These plots utilize the final data and present the simulation results in the sDA criteria table format, along with additional information about the expert and occupant assessments. A series of introductory 6 slide images explain the format, followed by an index to the 61 spaces, followed by the 61 spaces, one image per page.

The images of the 61 spaces also include subjective descriptive notes about the spaces. A few of the spaces also have occupant comments included in the notes section.

Results of linear regression equations by % time and % area

answer to questions: "I can work in this space with all the electric lights turned off (using only daylight)" and "The daylight in this room is always sufficient"

Likert score 1-9

strongly disagree << >>strongly agree

Percent of time, 9 sets of equations, 10% to 90%

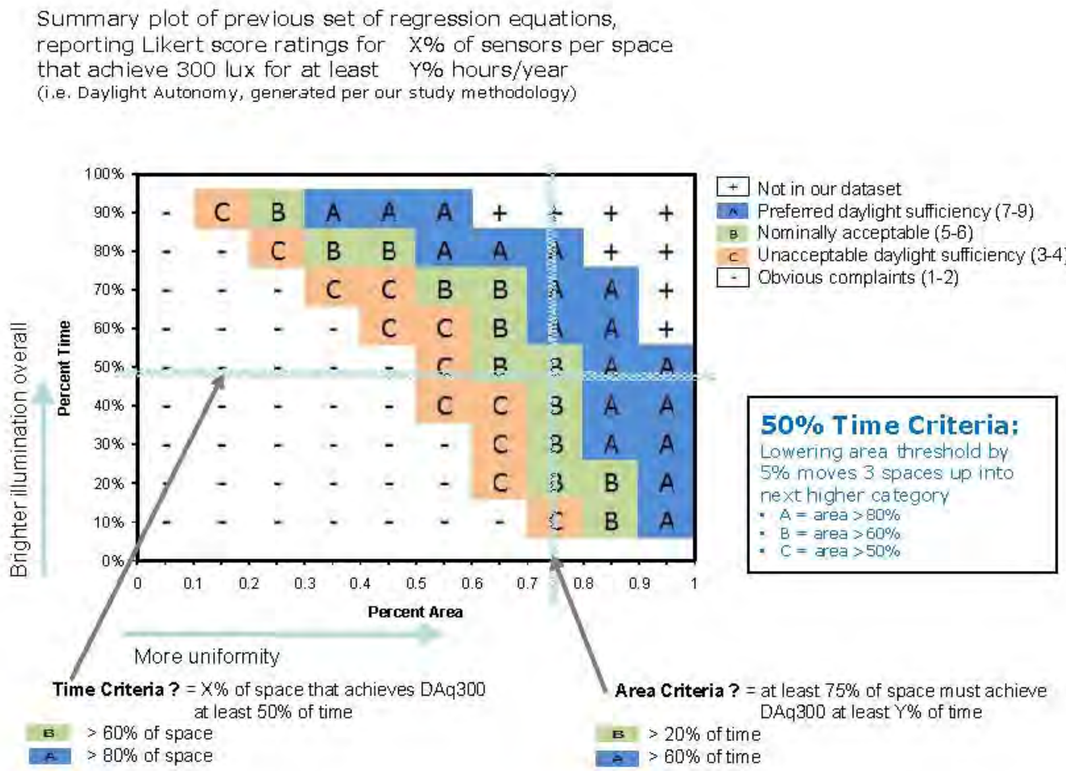
Bold = largest R^2 for that group:

- All 61 spaces
- Classrooms
- Offices
- Libraries/Lobbies

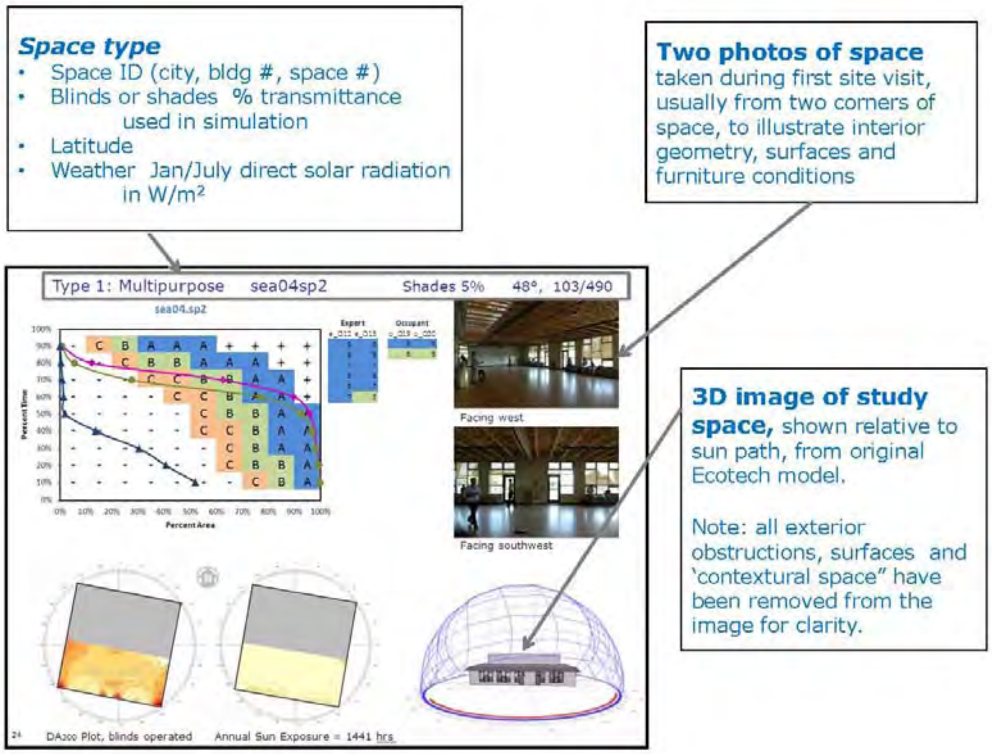
Percent of study area meeting DAq300 at least x% of time, predicted by weighted expert and occupant Likert scores 1-9

				C	C	B	B	A	A	A
DAq300 10% of time	AdjR2	1	2	3	4	5	6	7	8	9
All	0.1802	0.59	0.65	0.70	0.75	0.80	0.86	0.91	0.96	1.01
Class	0.1220	0.65	0.69	0.74	0.78	0.82	0.86	0.90	0.95	0.99
Office	0.2961	0.58	0.63	0.68	0.74	0.79	0.84	0.90	0.95	1.00
Other	**0.5267**	0.50	0.57	0.64	0.71	0.78	**0.85**	0.92	1.00	1.07
DAq300 20% of time	AdjR2									
All	0.1847	0.54	0.59	0.65	0.71	0.77	0.83	0.89	0.94	1.00
Class	0.1396	0.58	0.63	0.68	0.73	0.78	0.83	0.88	0.94	0.99
Office	0.3103	0.53	0.59	0.65	0.70	0.76	0.82	0.88	0.93	0.99
Other	0.5237	0.43	0.51	0.59	0.66	0.74	0.82	0.89	0.97	1.05
DAq300 30% of time	AdjR2									
All	0.1875	0.48	0.55	0.61	0.67	0.74	0.80	0.86	0.92	0.99
Class	0.1434	0.52	0.57	0.63	0.69	0.74	0.80	0.86	0.92	0.97
Office	0.3310	0.48	0.54	0.60	0.67	0.73	0.79	0.86	0.92	0.98
Other	0.5101	0.40	0.47	0.55	0.63	0.71	0.79	0.87	0.95	1.03
DAq300 40% of time	AdjR2									
All	0.1977	0.42	0.49	0.56	0.63	0.70	0.76	0.83	0.90	0.97
Class	0.1488	0.44	0.50	0.57	0.63	0.70	0.76	0.83	0.89	0.96
Office	0.3566	0.41	0.48	0.55	0.62	0.69	0.76	0.83	0.90	0.97
Other	0.4861	0.36	0.44	0.52	0.60	0.68	0.76	0.84	0.92	1.00
DAq300 50% of time	AdjR2									
All	**0.2103**	0.36	0.43	0.51	0.58	0.65	**0.73**	0.80	0.87	0.95
Class	0.1610	0.36	0.43	0.50	0.58	0.65	0.73	0.80	0.88	0.95
Office	0.3659	0.34	0.42	0.49	0.57	0.64	0.72	0.79	0.87	0.94
Other	0.4556	0.34	0.41	0.49	0.57	0.65	0.73	0.80	0.88	0.96
DAq300 60% of time	AdjR2									
All	0.2080	0.29	0.36	0.44	0.52	0.59	0.67	0.75	0.82	0.90
Class	0.1636	0.28	0.36	0.44	0.52	0.60	0.68	0.76	0.84	0.92
Office	**0.3720**	0.25	0.33	0.40	0.48	0.56	**0.64**	0.71	0.79	0.87
Other	0.3851	0.32	0.39	0.46	0.53	0.60	0.67	0.74	0.82	0.89
DAq300 70% of time	AdjR2									
All	0.1825	0.23	0.30	0.38	0.45	0.53	0.60	0.68	0.75	0.82
Class	0.1817	0.20	0.28	0.37	0.46	0.55	0.64	0.73	0.82	0.91
Office	0.3211	0.17	0.25	0.33	0.40	0.48	0.55	0.63	0.71	0.78
Other	0.2662	0.34	0.38	0.43	0.48	0.53	0.58	0.62	0.67	0.72
DAq300 80% of time	AdjR2									
All	0.1247	0.15	0.22	0.29	0.35	0.42	0.49	0.55	0.62	0.69
Class	**0.2117**	0.07	0.17	0.27	0.37	0.46	**0.56**	0.66	0.76	0.86
Office	0.2259	0.09	0.16	0.23	0.30	0.37	0.44	0.50	0.57	0.64
Other	0.1036	0.35	0.36	0.37	0.38	0.39	0.40	0.40	0.41	0.42
DAq300 90% of time	AdjR2									
All	0.0837	0.04	0.09	0.14	0.19	0.24	0.29	0.34	0.39	0.44
Class	0.1610	-0.05	0.03	0.12	0.20	0.29	0.38	0.46	0.55	0.64
Office	0.0823	0.07	0.10	0.12	0.15	0.18	0.21	0.24	0.27	0.30
Other	0.0968	0.18	0.18	0.19	0.19	0.20	0.20	0.21	0.21	0.22

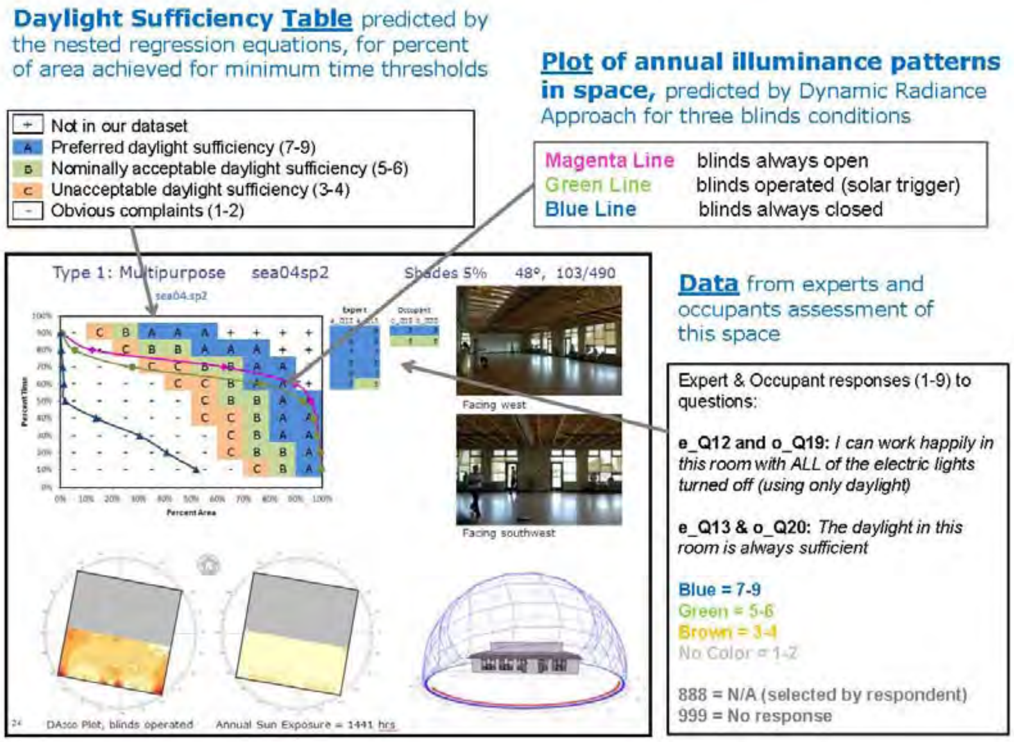
Regression prediction = **% of area** that must exceed DA300 that percent of time in order to produce that Likert rating



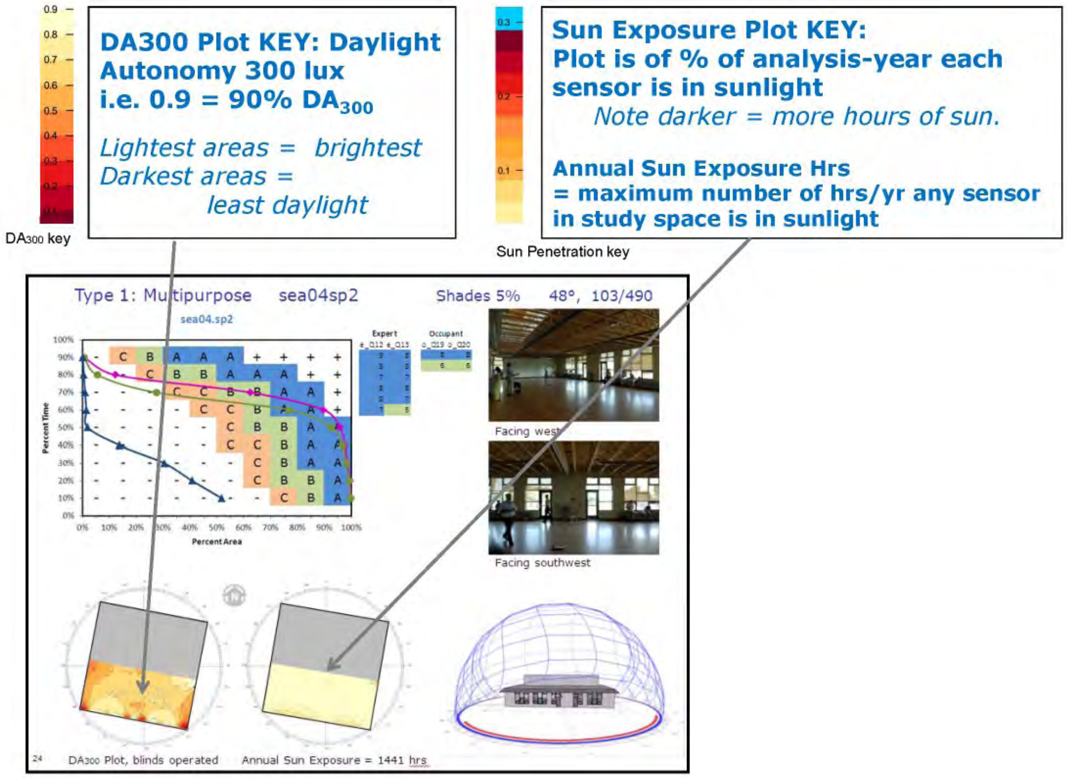
Summary plot of previous set of regression equations, reporting Likert score ratings for X% of sensors per space that achieve 300 lux for at least Y% hours/year
(i.e. Daylight Autonomy, generated per our study methodology)
Brighter illumination overall
Percent Time
Percent Area
More uniformity
Not in our dataset
Preferred daylight sufficiency (7-9)
Nominally acceptable (5-6)
Unacceptable daylight sufficiency (3-4)
Obvious complaints (1-2)
50% Time Criteria:
Lowering area threshold by 5% moves 3 spaces up into next higher category
A = area > 80%
B = area > 60%
C = area > 50%
Time Criteria ? = X% of space that achieves DAq300 at least 50% of time
B > 60% of space
A > 80% of space
Area Criteria ? = at least 75% of space must achieve DAq300 at least Y% of time
B > 20% of time
A > 60% of time



Space type
• Space ID (city, bldg #, space #)
• Blinds or shades % transmittance used in simulation
• Latitude
• Weather Jan/July direct solar radiation in W/m²
Two photos of space
taken during first site visit, usually from two corners of space, to illustrate interior geometry, surfaces and furniture conditions
3D image of study space, shown relative to sun path, from original Ecotech model.
Note: all exterior obstructions, surfaces and 'contextural space" have been removed from the image for clarity.
Type 1: Multipurpose sea04sp2 Shades 5% 48°, 103/490
sea04.sp2
Percent Time
Percent Area
Facing west
Facing southwest
DA300 Plot, blinds operated
Annual Sun Exposure = 1441 hrs



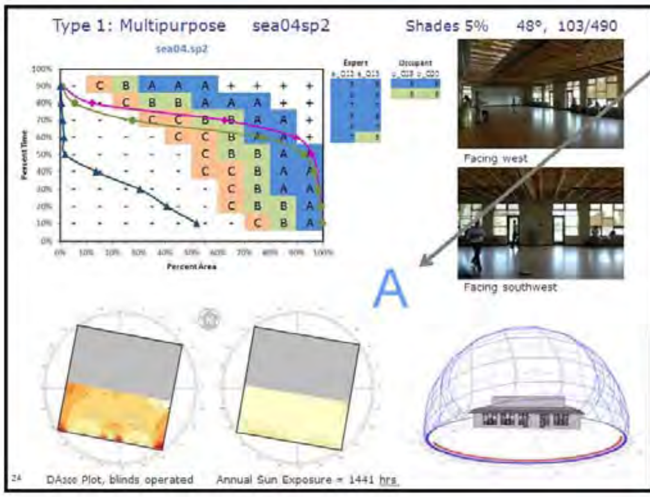
Daylight Sufficiency Table predicted by the nested regression equations, for percent of area achieved for minimum time thresholds
Not in our dataset
Preferred daylight sufficiency (7-9)
Nominally acceptable daylight sufficiency (5-6)
Unacceptable daylight sufficiency (3-4)
Obvious complaints (1-2)
Plot of annual illuminance patterns in space, predicted by Dynamic Radiance Approach for three blinds conditions
Magenta Line blinds always open
Green Line blinds operated (solar trigger)
Blue Line blinds always closed
Type 1: Multipurpose sea04sp2 Shades 5% 48°, 103/490
Percent Time
Percent Area
Facing west
Facing southwest
DA300 Plot, blinds operated
Annual Sun Exposure = 1441 hrs
Data from experts and occupants assessment of this space
Expert & Occupant responses (1-9) to questions:
e_Q12 and o_Q19: I can work happily in this room with ALL of the electric lights turned off (using only daylight)
e_Q13 & o_Q20: The daylight in this room is always sufficient
Blue = 7-9
Green = 5-6
Brown = 3-4
No Color = 1-2
888 = N/A (selected by respondent)
999 = No response


DA300 Plot KEY: Daylight Autonomy 300 lux
i.e. 0.9 = 90% DA300
Lightest areas = brightest
Darkest areas = least daylight
DA300 key
Sun Exposure Plot KEY:
Plot is of % of analysis-year each sensor is in sunlight
Note darker = more hours of sun.
Annual Sun Exposure Hrs
= maximum number of hrs/yr any sensor in study space is in sunlight
Sun Penetration key
Type 1: Multipurpose sea04sp2
Shades 5% 48°, 103/490
sea04.sp2
Percent Time
Percent Area
Facing west
Facing southwest
DA300 Plot, blinds operated
Annual Sun Exposure = 1441 hrs

Number of spaces (n=61) passing various Time Criteria

50% time has a slightly higher R^2 for the three space types taken together

Time Criteria:	10%	20%	30%	40%	50%	60%	70%	80%	90%
# A's	35	30	36	31	29	29	16	18	16
# B's	5	12	3	6	9	4	14	16	8
# C's	5	7	8	11	6	14	15	5	7
Total A+B	40	42	39	37	38	33	30	34	24
Total A+B+C	45	49	47	48	44	47	45	39	31



Grade A or B, based on simulation results for space, at 50% DA_{300}

- A = >80% area
- B = >60% area

Note: all exterior obstructions and 'contextural space" have been removed from the image for clarity.

50%
32
9
6
41
47

Sensitivity Test:
Lowering area threshold by 5% moves 3 spaces up into next higher category

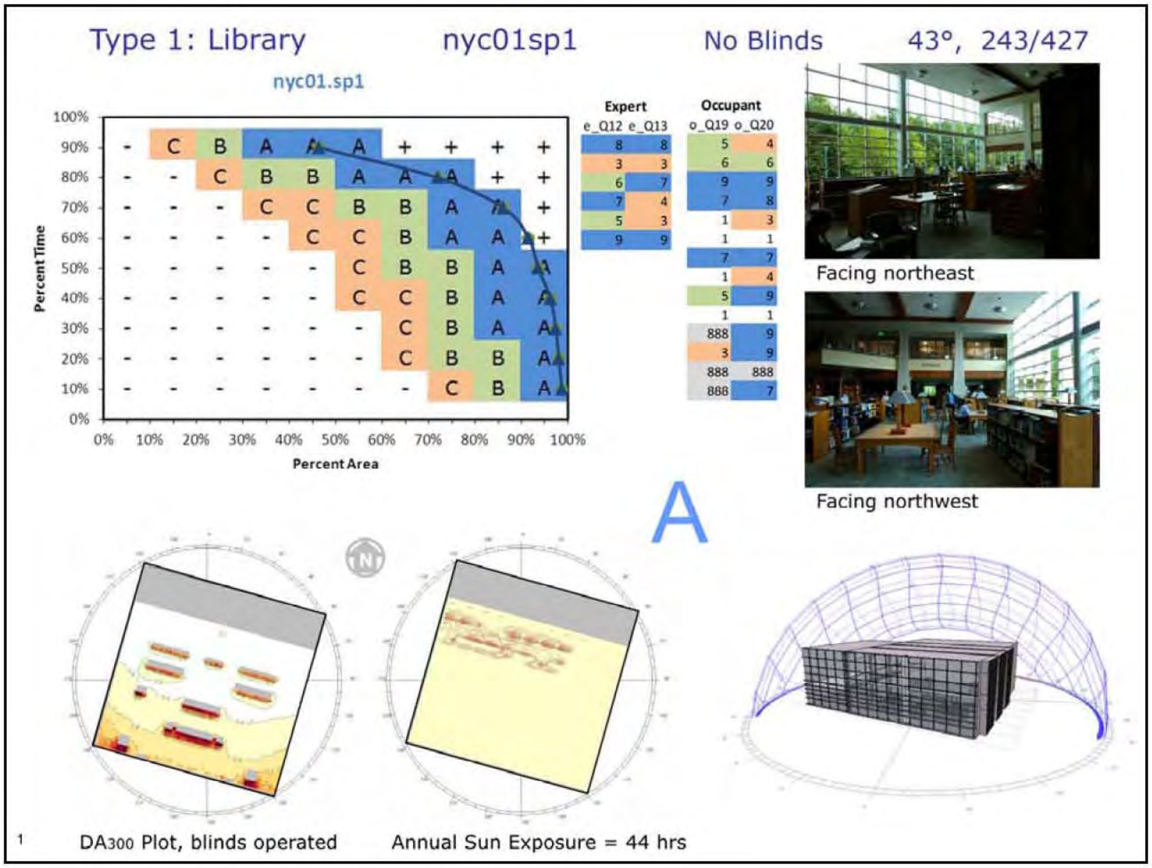
- A from >79.5% to >74.5%
- B from >59.5% to >54.5%
- C form >49.5% to >44.5%

Index of 61 spaces in alphabetic order, page 1:

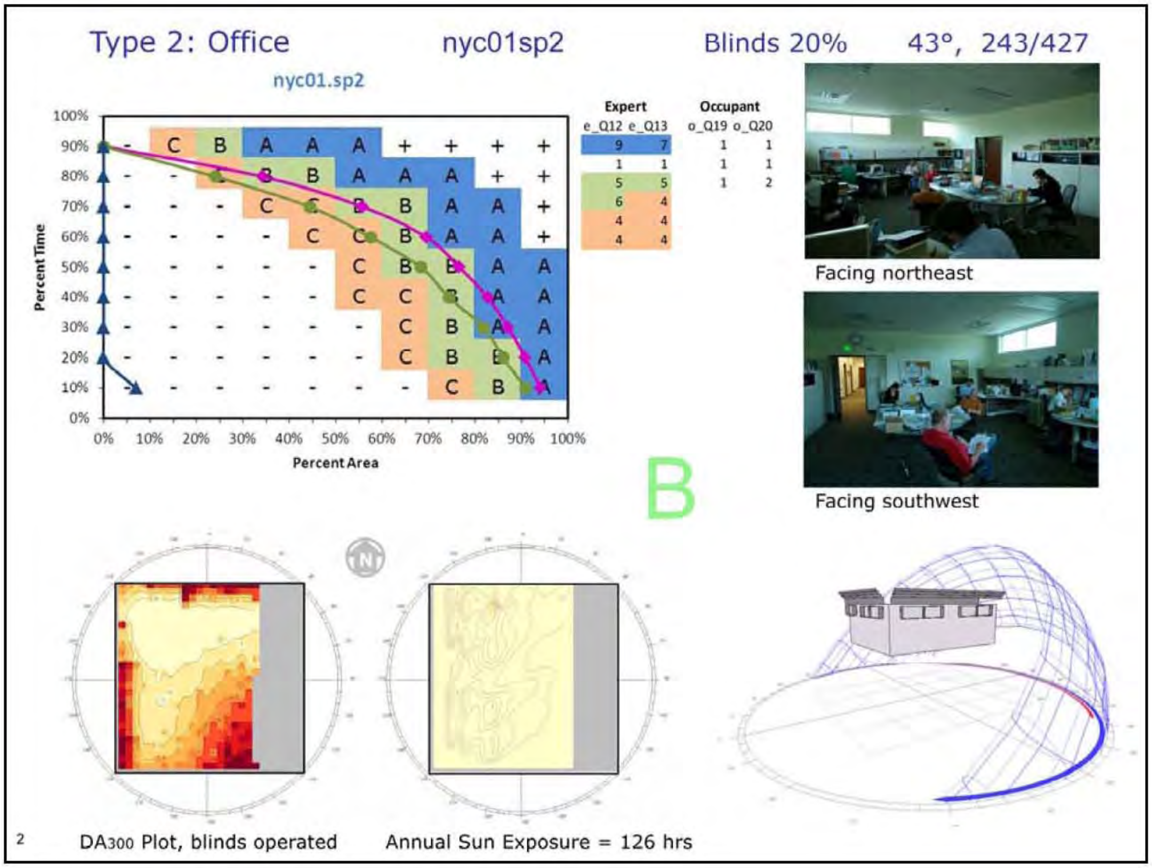
Order	ID	type	Space Type	Weather Locale	Latitude	Window coverings modeled	Primary View	Other daylight sources	Study area	Window to interior wall area
1	NYC01.SP1	1	Library	Albany NY	43	no blinds	large north		5155	100%
2	NYC01.SP2	2	Office	Albany NY	43	Blinds 20%	none	clerestory-2	683	16%
3	NYC02.SP1	2	Office	Albany NY	43	Blinds 20%	south		2294	15%
4	NYC02.SP2	3	Classroom	Albany NY	43	Blinds 20%	north and south		1049	10%
5	NYC04.SP1	2	Office	New York City	41	Shades 5%	south and west		3096	100%
6	NYC04.SP2	2	Office	New York City	41	Shades 5%	west and north		3147	97%
7	NYC05.SP1	3	Classroom	New York City	41	Shades 5%	southwest	light shelf	1068	19%
8	NYC05.SP2	3	Classroom	New York City	41	Shades 5%	southwest	light shelf	883	35%
9	NYC08.SP1	3	Classroom	New York City	41	Shades 5%	south	light shelf	642	38%
10	NYC08.SP2	3	Classroom	New York City	41	Shades 5%	south	light shelf	642	38%
11	NYC09.SP1	2	Office	New York City	41	no blinds	south		1034	79%
12	SEA01.SP1	2	Office	Seattle	48	blinds 20%	north		3218	52%
13	SEA01.SP2	2	Office	Seattle	48	blinds 20%	south		2779	70%
14	SEA01.SP3	2	Office	Seattle	48	blinds 20%	east		1696	56%
15	SEA02.SP1	1	Library	Seattle	48	blinds 20%	none	clerestory-4	2268	21%
16	SEA02.SP2	3	Classroom	Seattle	48	blinds 20%	south	light shelf	896	17%
17	SEA02.SP3	3	Classroom	Seattle	48	blinds 20%	south	light shelf	896	14%
18	SEA03.SP1	3	Classroom	Seattle	48	Shades 5%	south		1065	69%
19	SEA03.SP2	1	Lobby	Seattle	48	no blinds	none	Monitors	6450	32%
20	SEA04.SP1	1	Lobby	Seattle	48	no blinds	none	Monitors	2806	16%
21	SEA04.SP2	1	Multipurpose	Seattle	48	Shades 5%	west	Monitors	2343	19%
22	SEA06.SP1	2	Office	Seattle	48	Shades 5%	west		1567	50%
23	SEA06.SP2	2	Office	Seattle	48	Shades 5%	west		3052	97%
24	SEA06.SP3	3	Conference	Seattle	48	Shades 5%	west		560	47%
25	SEA06.SP4	1	Library	Seattle	48	no blinds	translucent		missing	missing
26	SEA07.SP1	2	Office	Seattle	48	Shades 5%	north	Skylights	2405	71%
27	SEA07.SP2	1	Lobby	Seattle	48	Shades 5%	south		2276	86%
28	SEA07.SP3	2	Office	Seattle	48	Shades 5%	north		2920	76%
29	SFO01.SP1	1	Library	Oakland	38	no blinds	translucent	translucent	1491	11%
30	SFO01.SP2	3	Classroom	Oakland	38	Blinds 20%	south		933	42%
31	SFO01.SP4	3	Classroom	Oakland	38	Blinds 20%	north	Skylights	933	42%

Index of 61 spaces in alphabetic order, page 2:

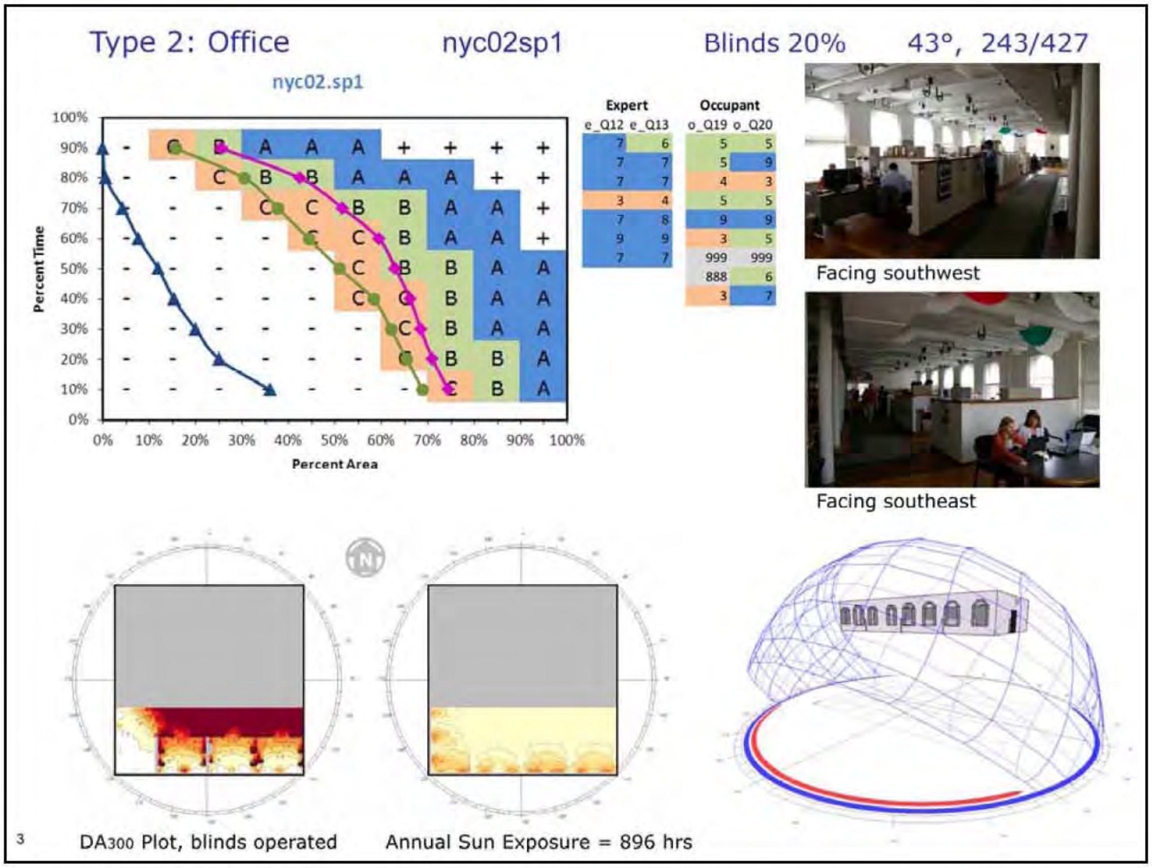
Order	ID	type	Space Type	Weather Locale	Latitude	Window coverings modeled	Primary View	Other daylight sources	Study area	Window to interior wall area
32	SFO02.SP1	3	Classroom	Oakland	38	Blinds 20%	east/west	Skylights	897	18%
33	SFO02.SP3	3	Classroom	Oakland	38	Blinds 20%	east/west		897	18%
34	SFO04.SP1	2	Office	San Francisco	38	Shades 5%	south		3344	54%
35	SFO04.SP2	2	Office	San Francisco	38	Blinds 20%	north		6100	100%
36	SFO05.SP1	2	Office	San Francisco	38	Blinds 20%	north		3145	56%
37	SFO05.SP2	2	Office	San Francisco	38	Blinds 20%	Atrium		3834	62%
38	SFO05.SP3	3	Conference	San Francisco	38	no blinds	Atrium		missing	missing
39	SFO05.SP4	2	Office	San Francisco	38	Blinds 20%	south		3145	56%
40	SFO06.SP1	1	Lobby	San Francisco	38	no blinds	none	Skylights	missing	missing
41	SFO06.SP2	1	Library	San Francisco	38	no blinds	none	clerestory -2	missing	missing
42	SFO07.SP1	1	Library	San Francisco	38	Shades 5%	none	clerestory -4	3822	17%
43	SMF02.SP1	1	Library	Sacramento	39	no blinds	south		1500	69%
44	SMF03.SP1	3	Classroom	Sacramento	39	Shades 5%	norht/south	clerestory	875	51%
45	SMF03.SP2	3	Classroom	Sacramento	39	Shades 5%	north/south	clerestory	875	47%
46	SMF04.SP1	2	Office	Sacramento	39	Blinds 20%	south	light shelf	1438	46%
47	SMF04.SP2	2	Office	Sacramento	39	Blinds 20%	north		1713	61%
48	SMF04.SP3	2	Office	Sacramento	39	Blinds 20%	north	Skylights	1713	61%
49	SMF05.SP1	2	Office	Sacramento	39	no blinds	none	Skylights	5067	0%
50	SMF06.SP1	1	Library	Sacramento	39	Blinds 20%	north	Skylights	1352	50%
51	SMF06.SP2	3	Classroom	Sacramento	39	Shades 5%	north/west	Skylights	739	31%
52	SMF06.SP3	3	Classroom	Sacramento	39	Shades 5%	south/east	Skylights	1045	30%
53	SMF07.SP1	1	Library	Sacramento	39	no blinds	north	Skylights	3774	22%
54	SMF08.SP1	3	Classroom	Tahoe	40	Blinds 20%	south	clerestory	751	47%
55	SMF08.SP2	1	Library	Tahoe	40	Blinds 20%	south	clerestory	1343	30%
56	SMF08.SP3	3	Classroom	Tahoe	40	Blinds 20%	north	clerestory	799	47%
57	SMF09.SP1	1	Multipurpose	Tahoe	40	no blinds	south/north	Monitors	4174	27%
58	SMF10.SP1	3	Classroom	Sacramento	39	Shades 5%	east/west	Tubular skylights	899	12%
59	SMF10.SP2	3	Classroom	Sacramento	39	Shades 5%	east/west		899	13%
60	SMF11.SP1	2	Office	Sacramento	39	Blinds 20%	north	Skylights	4190	83%
61	SMF11.SP2	2	Office	Sacramento	39	no blinds	none	borrowed skylight	missing	missing



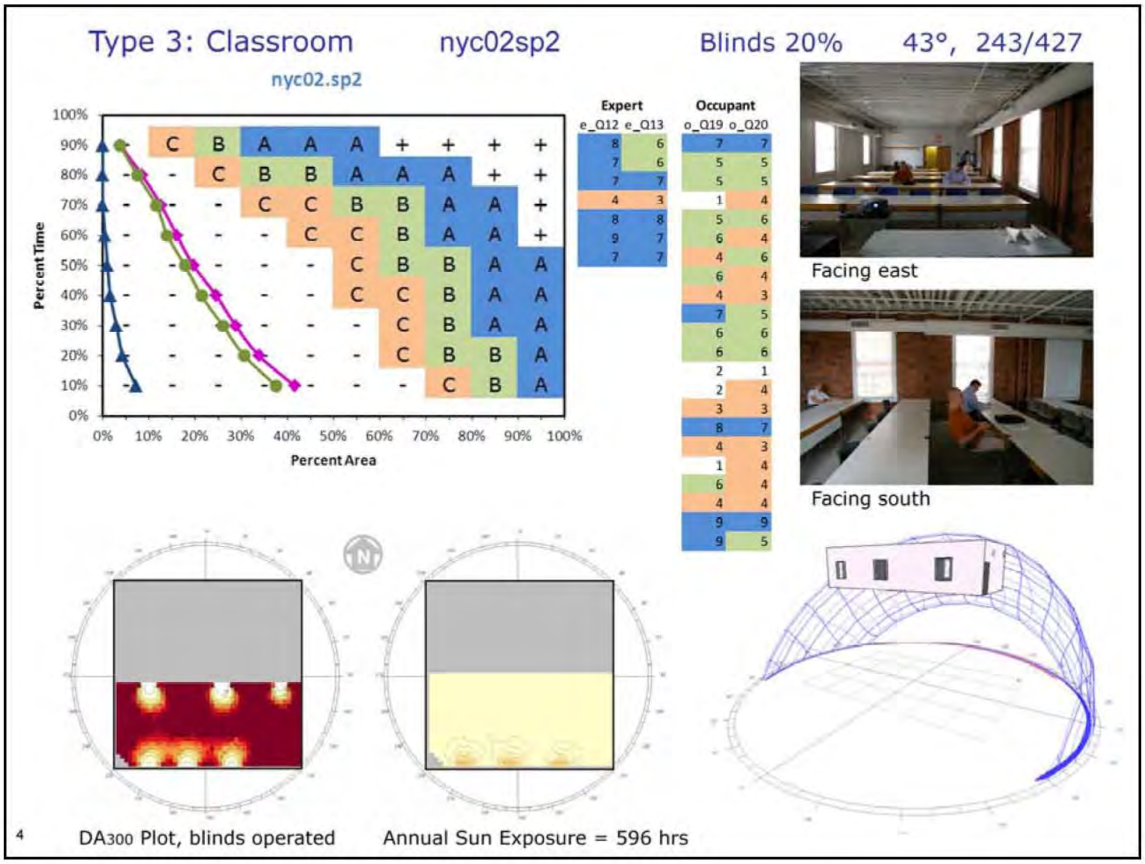
Library in upstate New York, with large window looking north onto patio with trees
beyond. Annual plot over predicts occupant response.



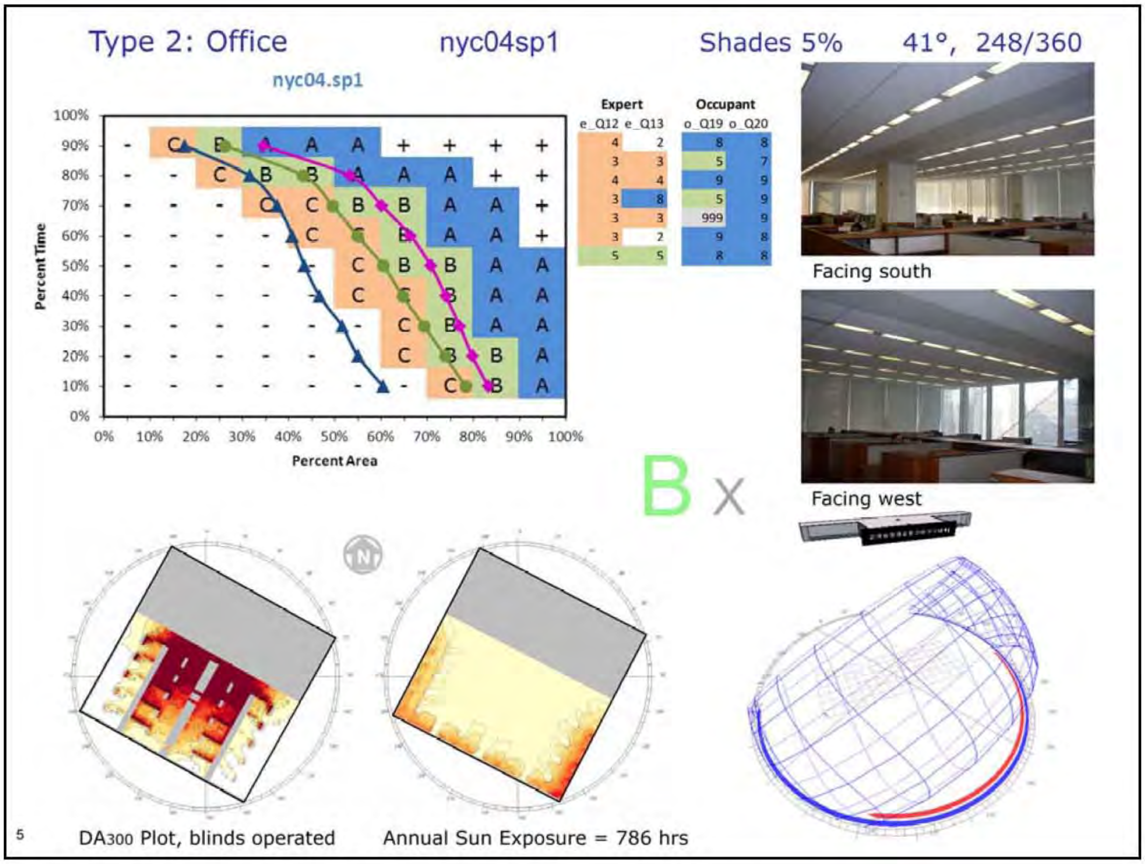
Offices in upstate New York, high windows face west and north with vertical blinds usually deployed. Annual plot under predicts three occupants, but correctly predicts experts



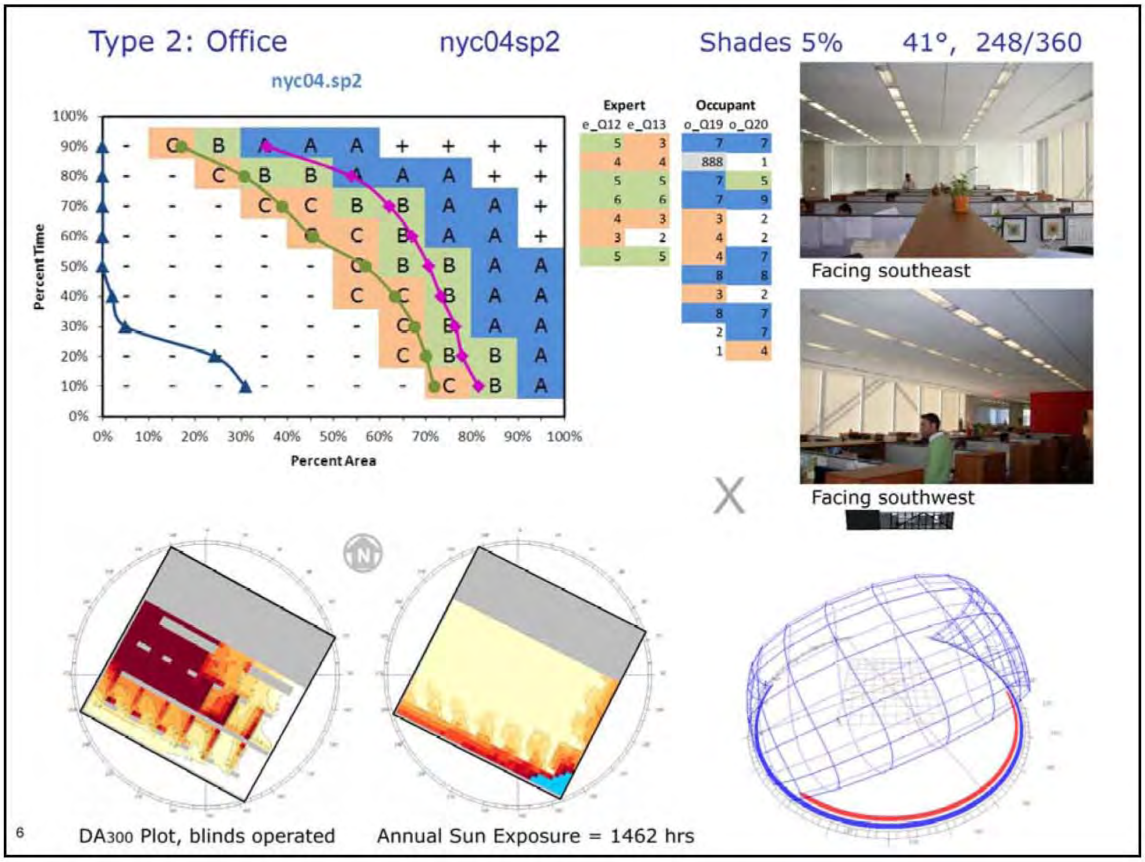
Offices in upstate New York, punched windows face south, looking at streetscape obstructions blocking morning and afternoon winter sun. Work area one cubical deep. Annual plot under predicts occupant assessment. White surfaces may contribute



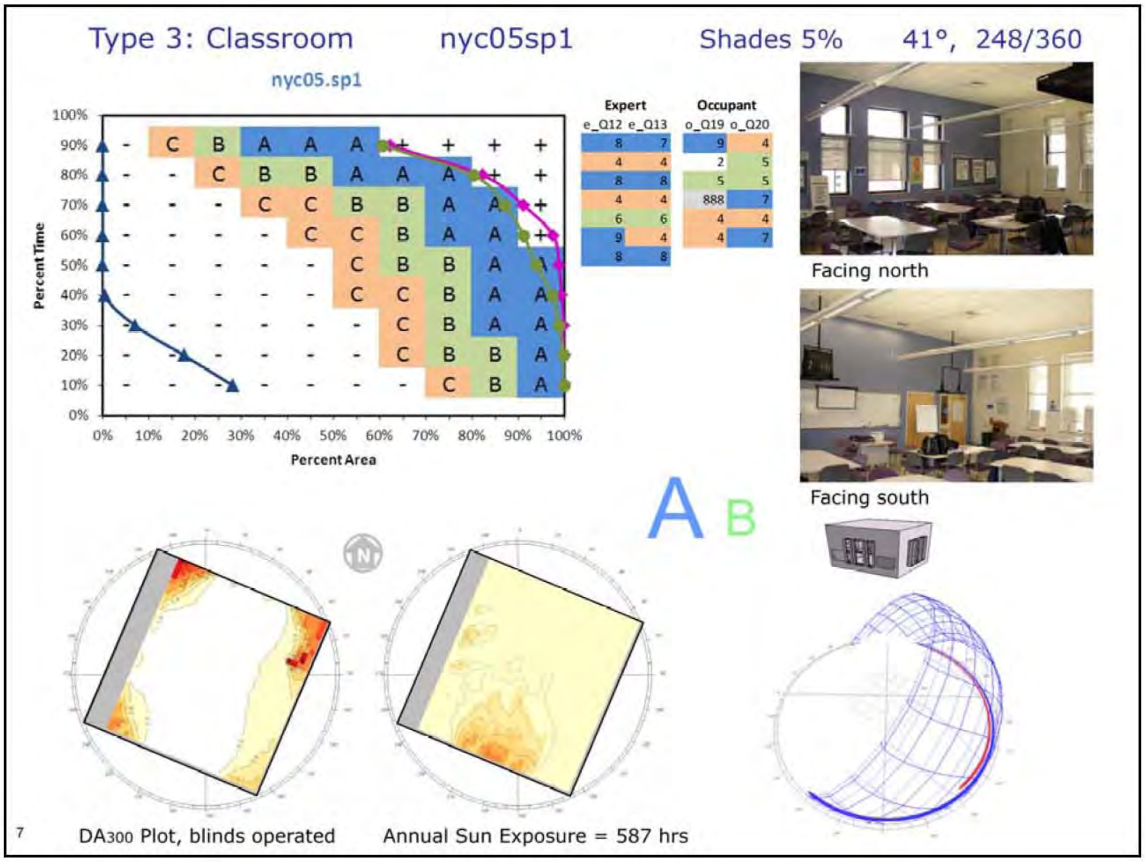
Adult classroom in upstate NY. North and south punched windows look out to walls of adjacent brick buildings, with substantial exterior shading fall, winter and spring. Annual plot greatly under predicts occupant assessment.



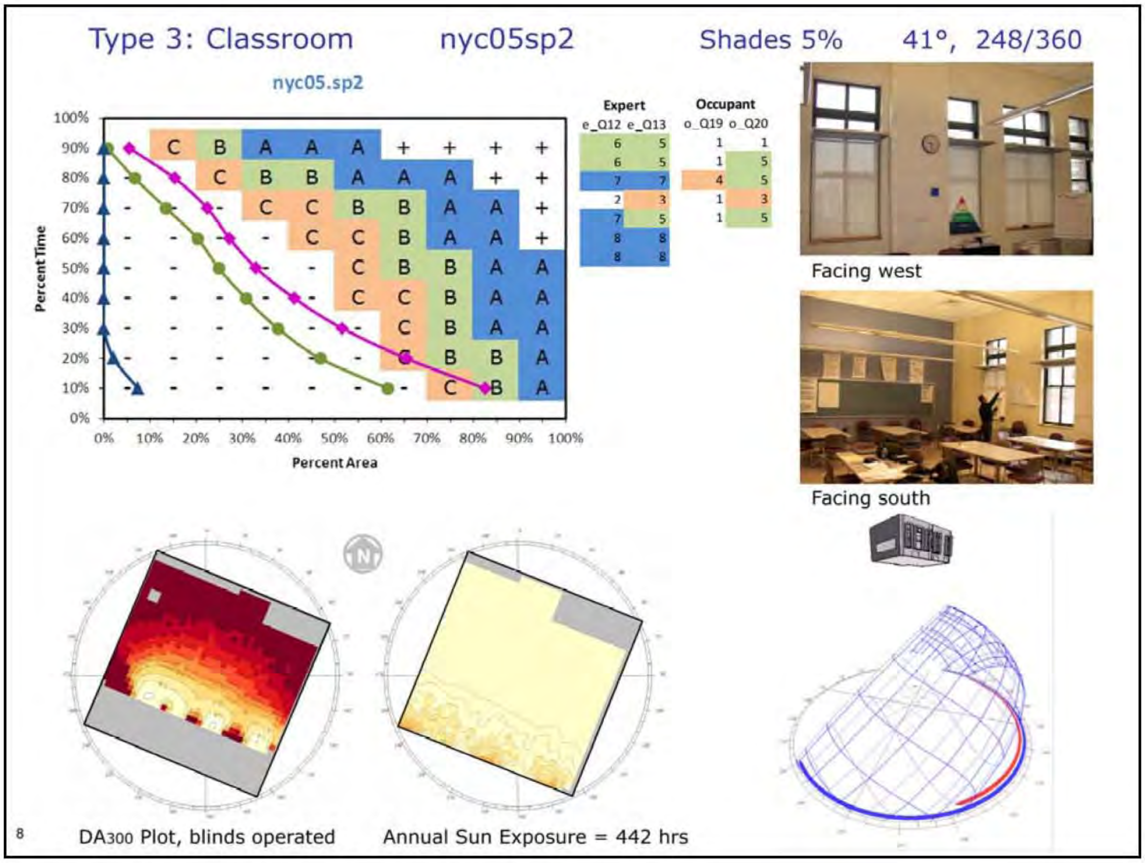
Office in Manhattan, with windows on three sides, primary facing SW, with add'l glazing to SE and NW. Automated shades and highly granular photocontrol of T5 lights. Annual plot predicts experts, but under predicts



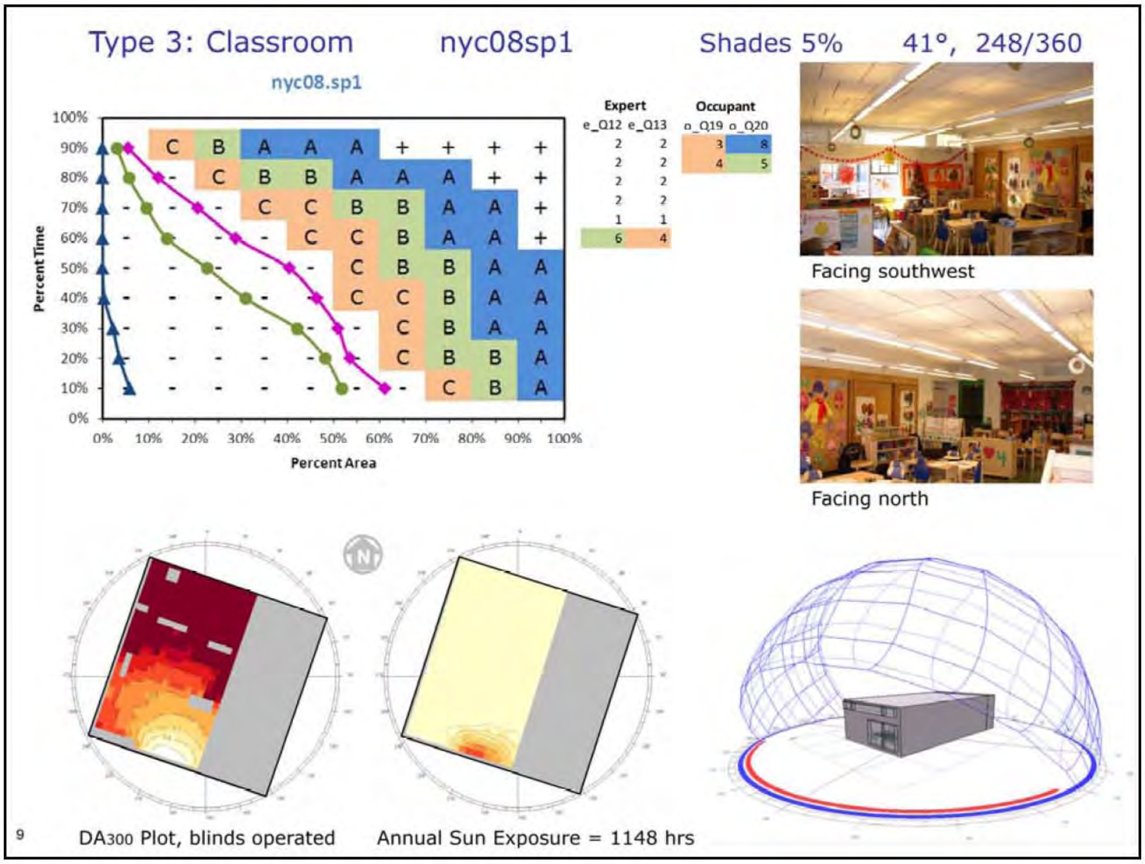
Office in Manhattan, with primary windows facing SW, and add'l glazing to SE. Automated shades and highly granular photocontrol of T5 lights. Annual plot



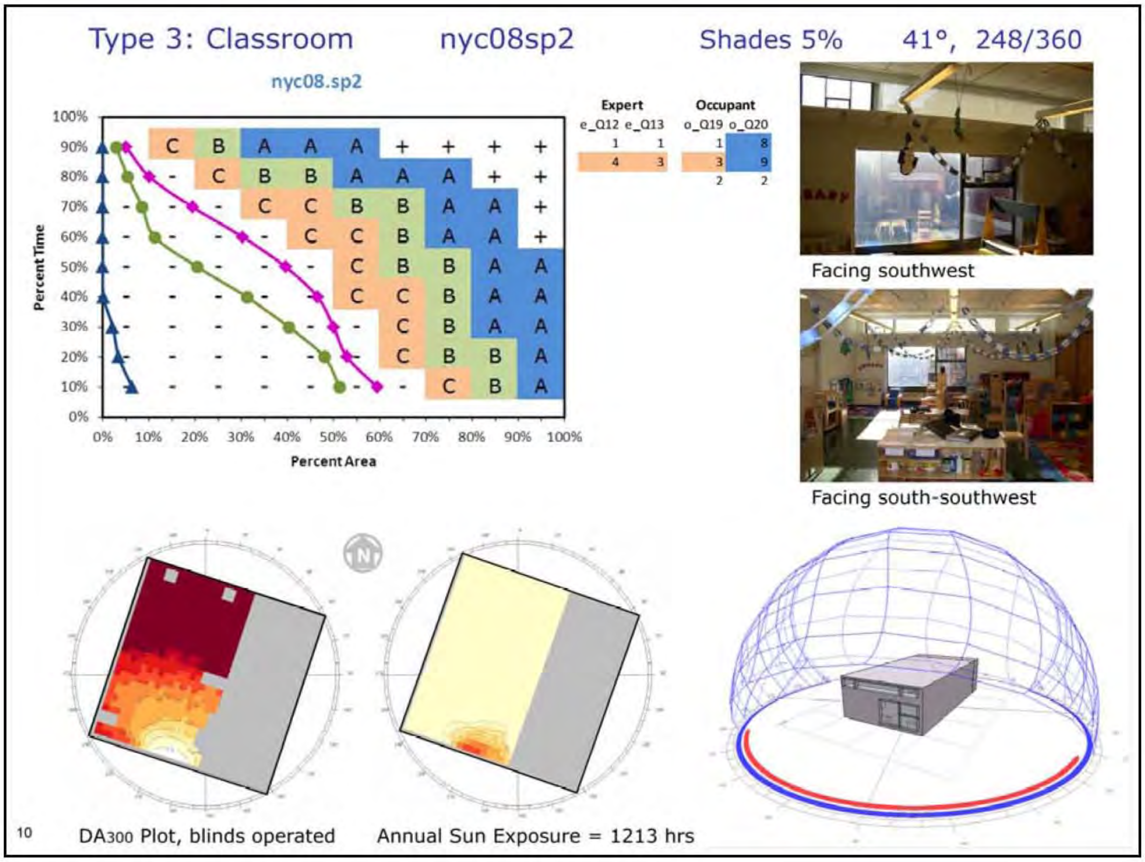
Adult ed classroom in Manhattan, windows facing south east, northwest and north east, with small light shelves for upper northwest (!) windows only. No sun protection for upper windows. Annual plot over predicts occupant and



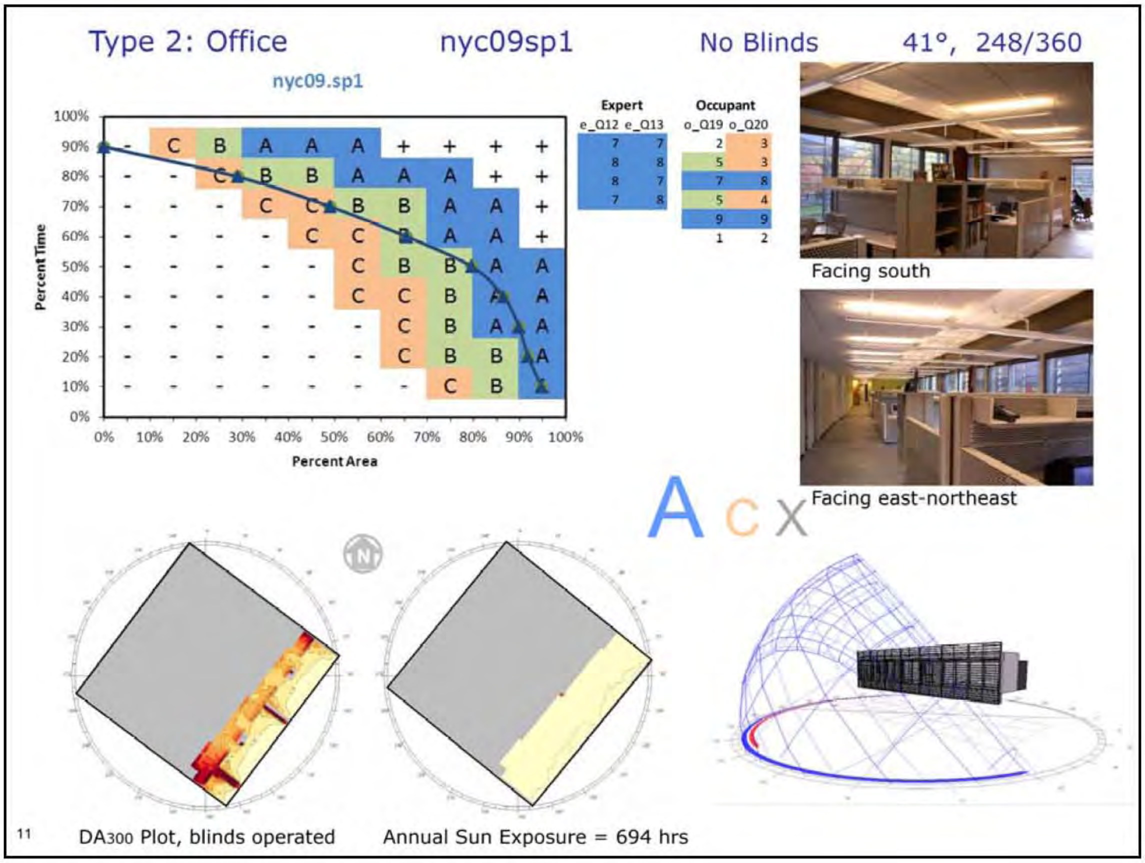
Adult ed classroom in Manhattan, windows facing south east, with small lightshelves for upper windows. No sun protection for upper windows. Annual plot under predicts occupant and expert assessments. View may contribute to



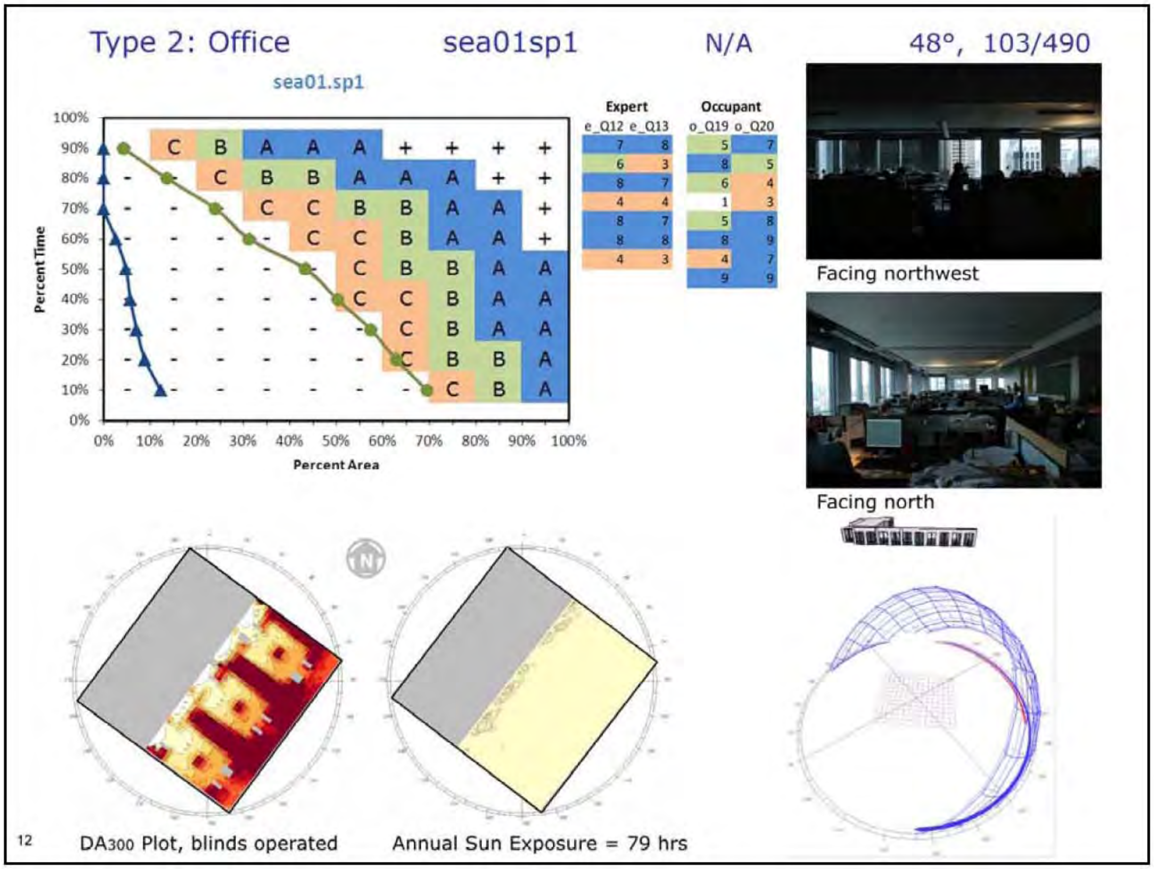
Preschool classroom in Brooklyn, south facing view window, with clerestory above lightshelf. Annual plot under predicts occupant assessments, but agrees with experts. Back half of room with no daylight source.



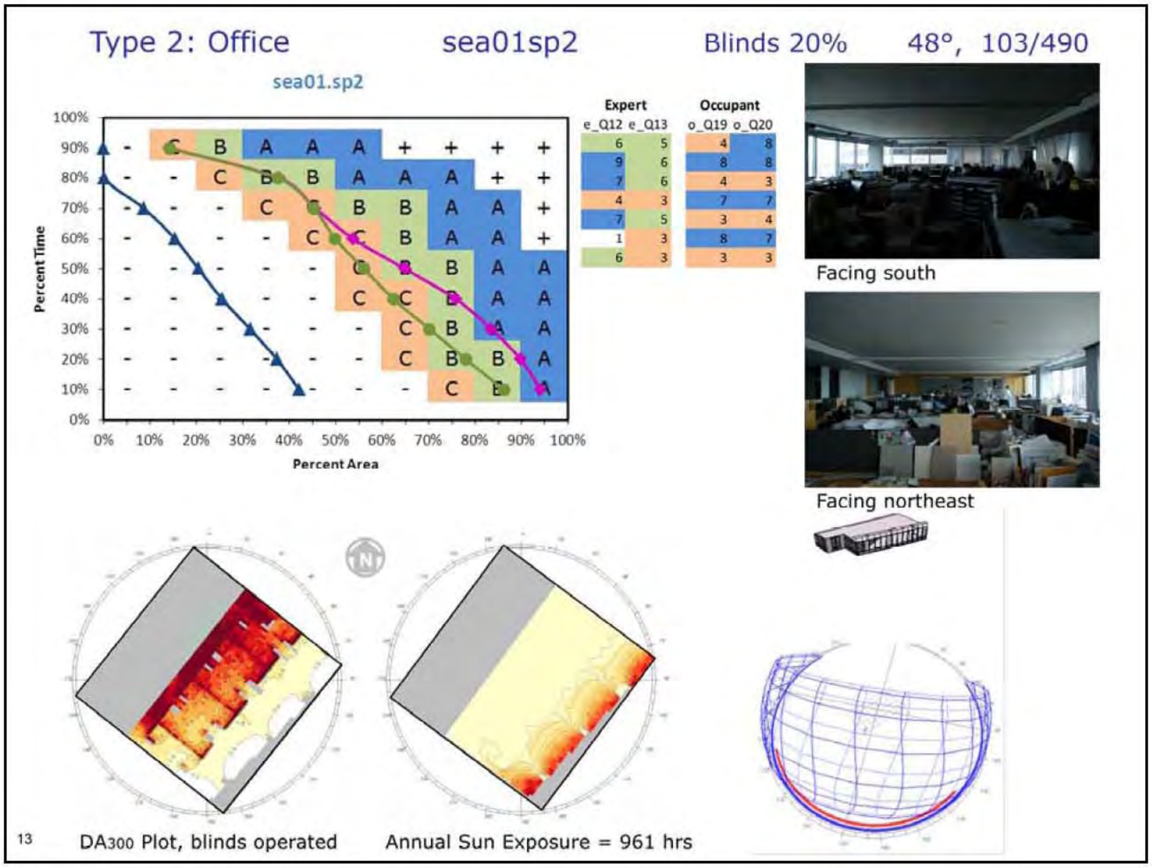
Preschool classroom in Brooklyn, south facing view window, with clerestory above lightshelf. Annual plot under predicts too few assessments. Back half of



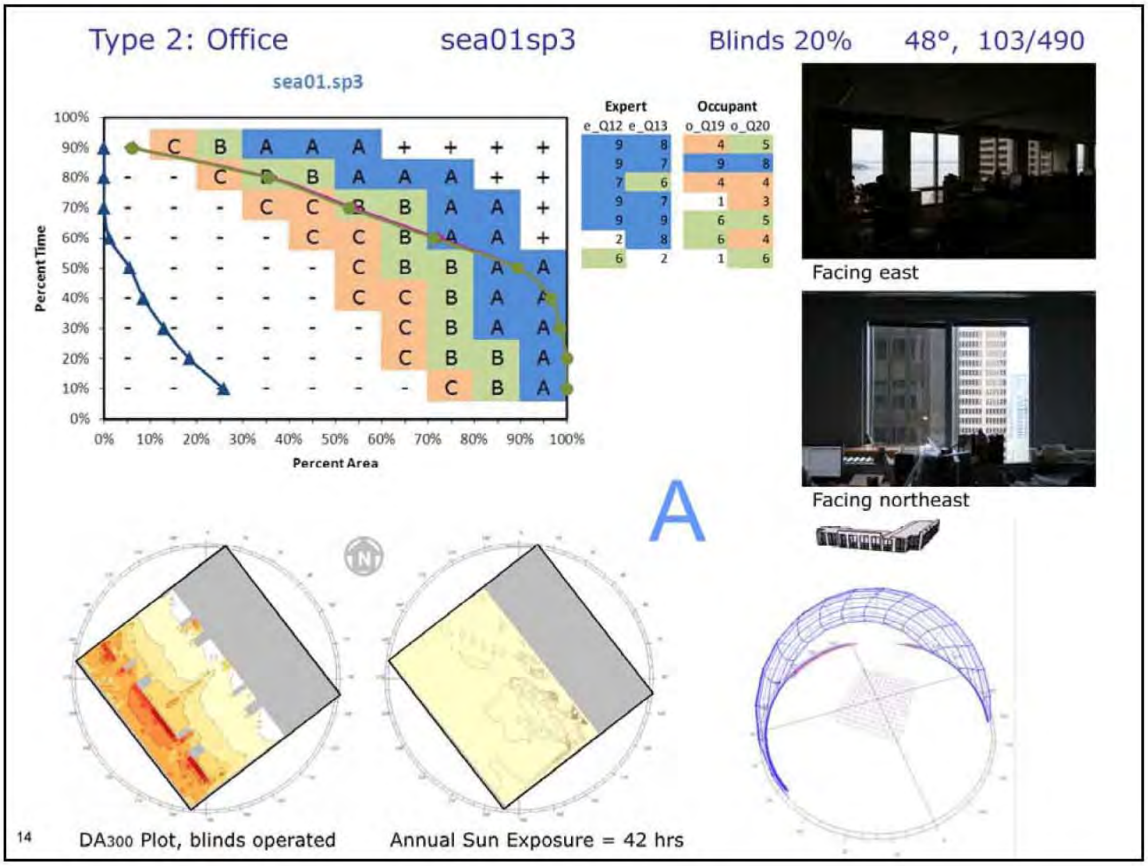
Office in Queens, south facing with exterior shading, view to woodland. Office



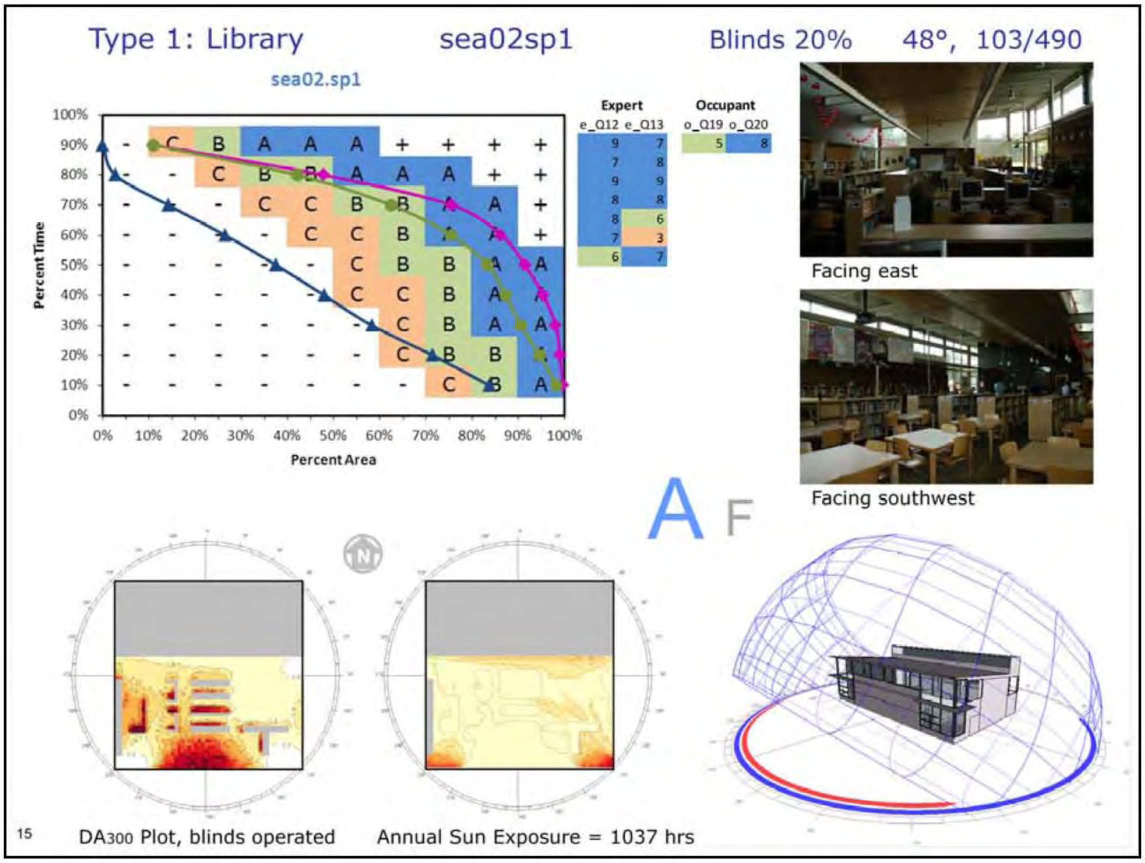
Highrise open office in Seattle. Space facing NW, with large building immediately adjacent blocking most views. Two cubicles deep, with file area along back circulation with wall at back end



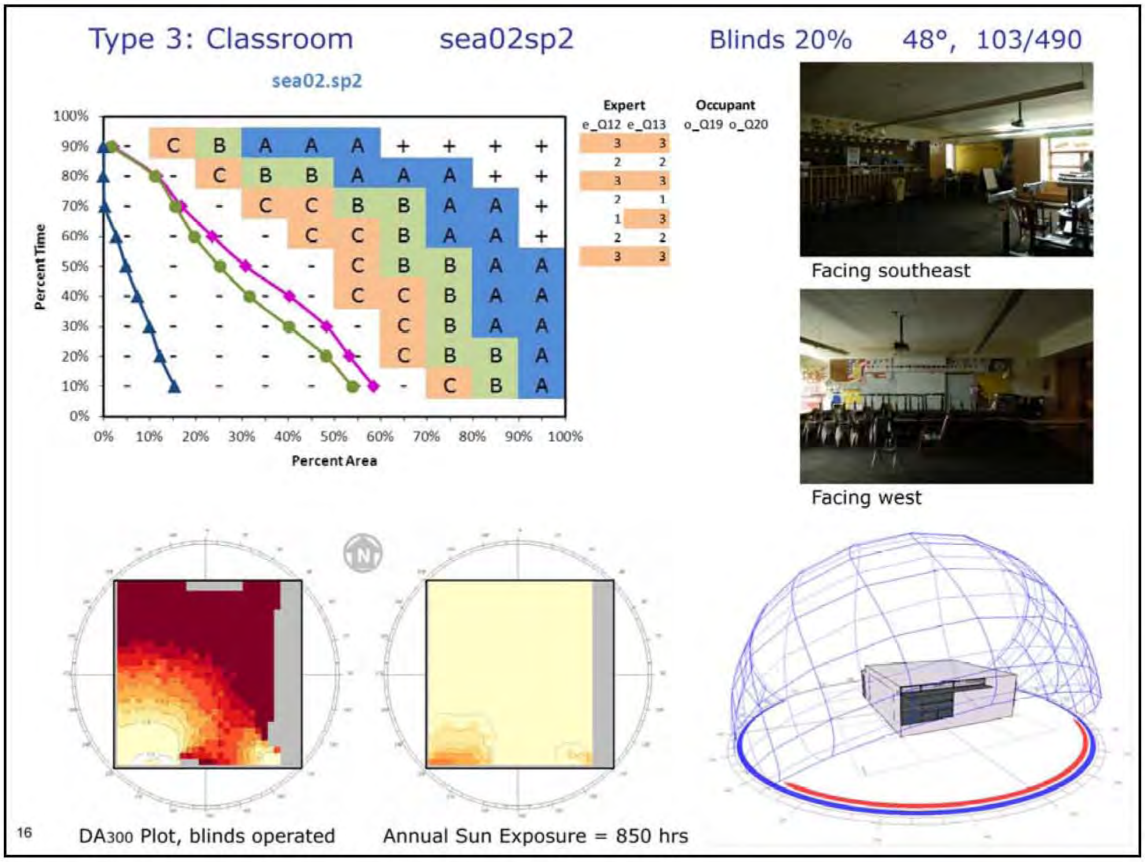
Highrise open office in Seattle. Space facing SE, with expansive views to horizon,



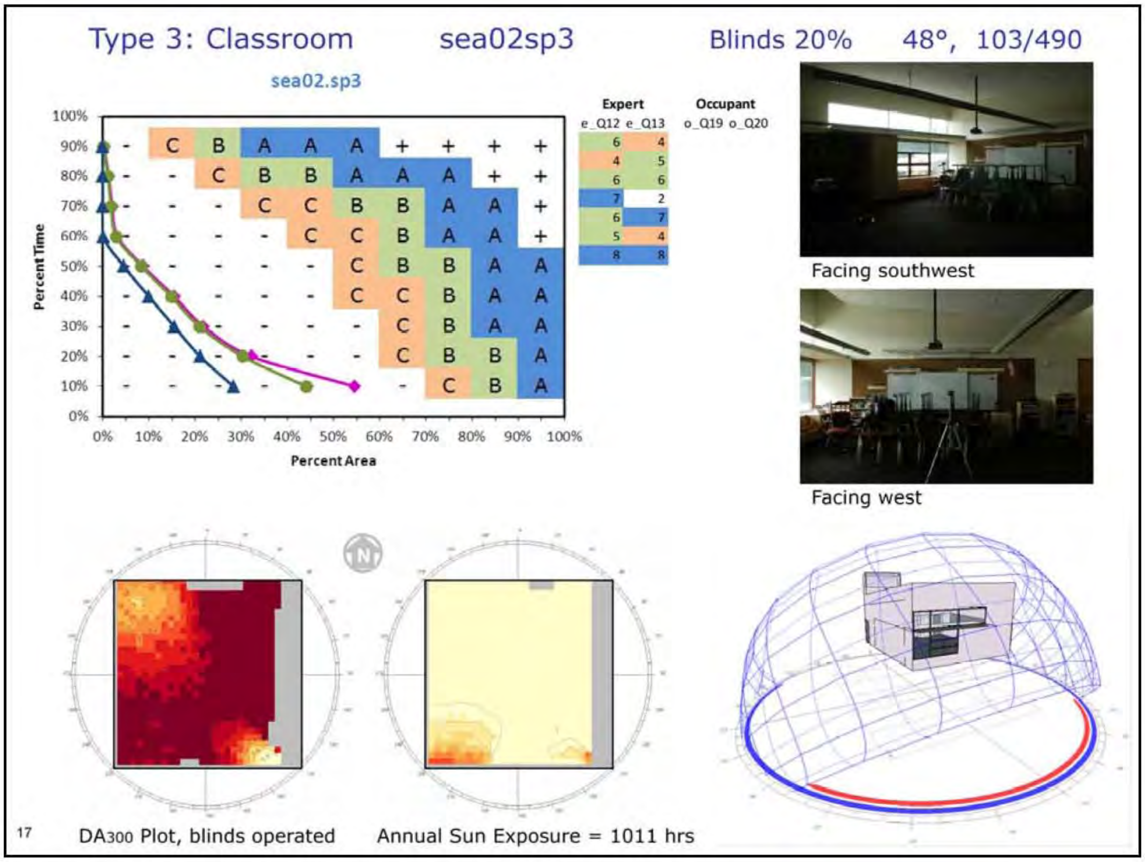
Highrise open office in Seattle. Space facing NE, with expansive views to horizon, and some adjacent high rises blocking eastern sun. Additional views to NW and SE.



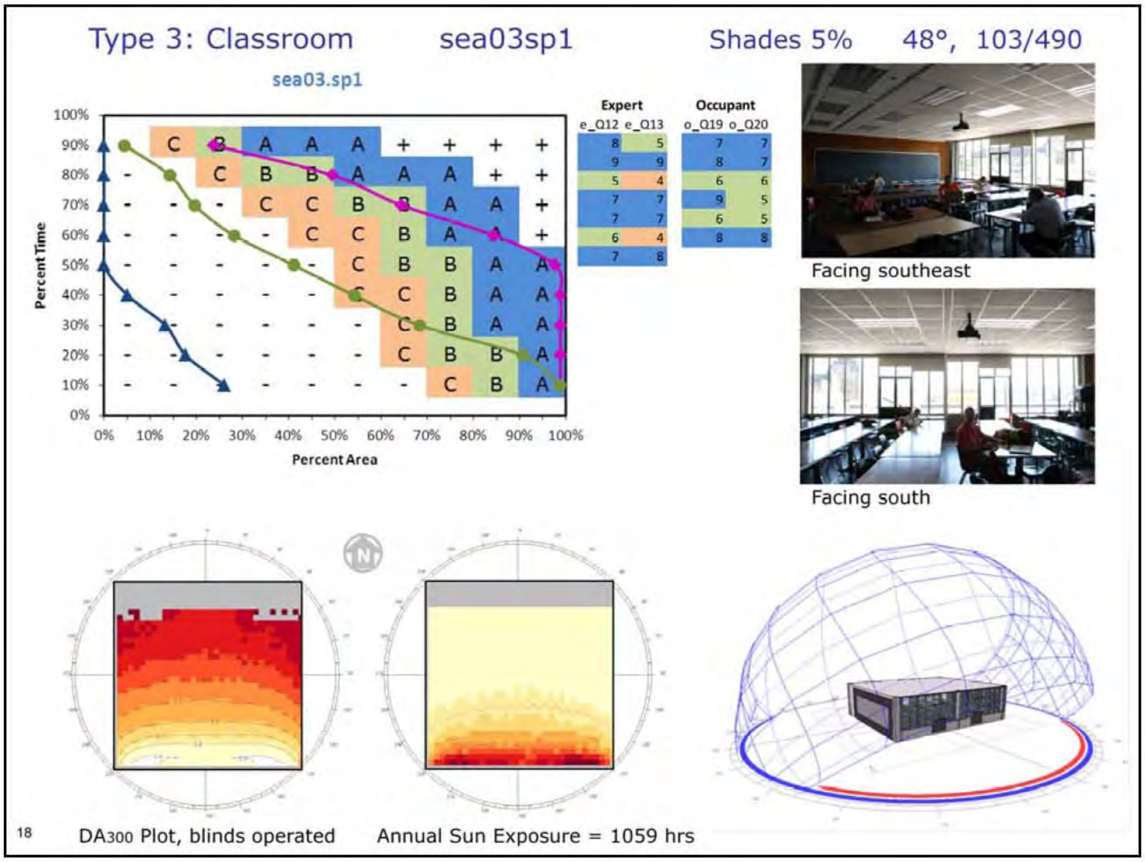
Elementary school library in Seattle. High windows to east, south and west, views at corners. Monitor to north. Only one occupant assessment (librarian).



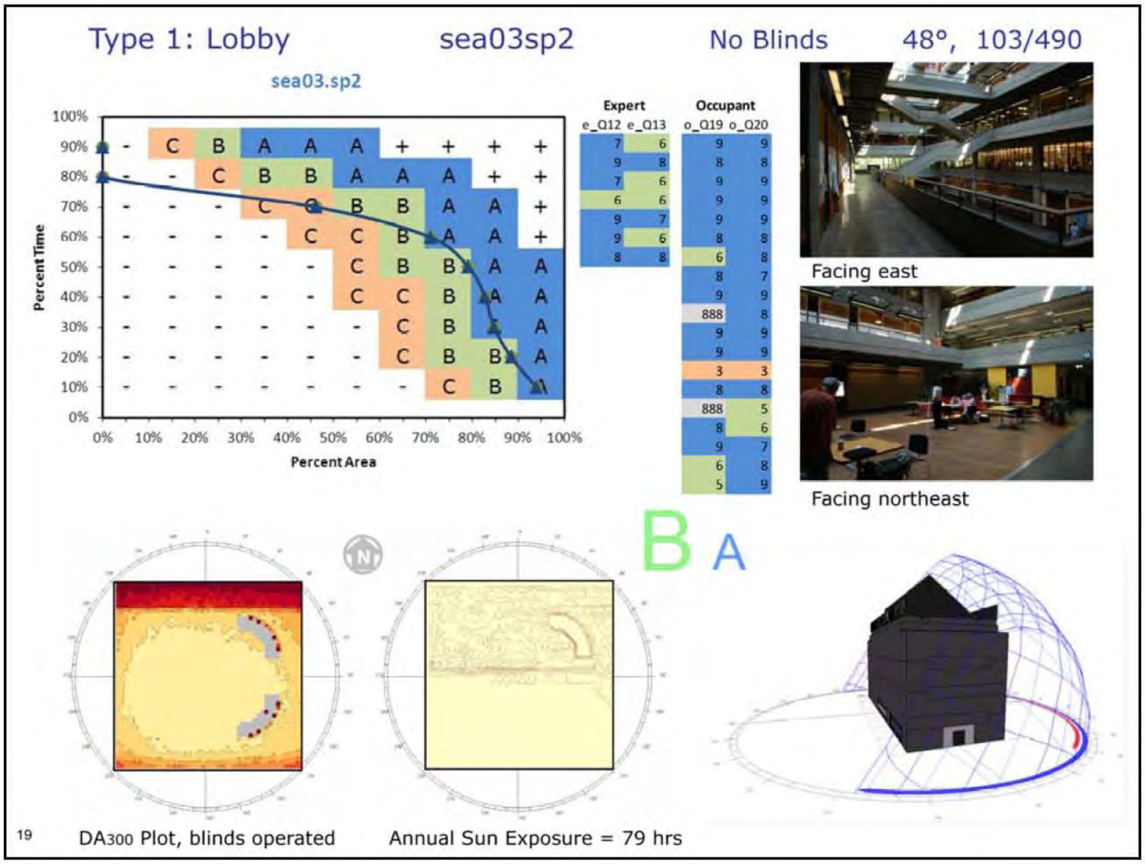
Elementary school classroom in Seattle. South facing view and high windows with light shelf. First floor. No occupant assessments. Annual plot greatly



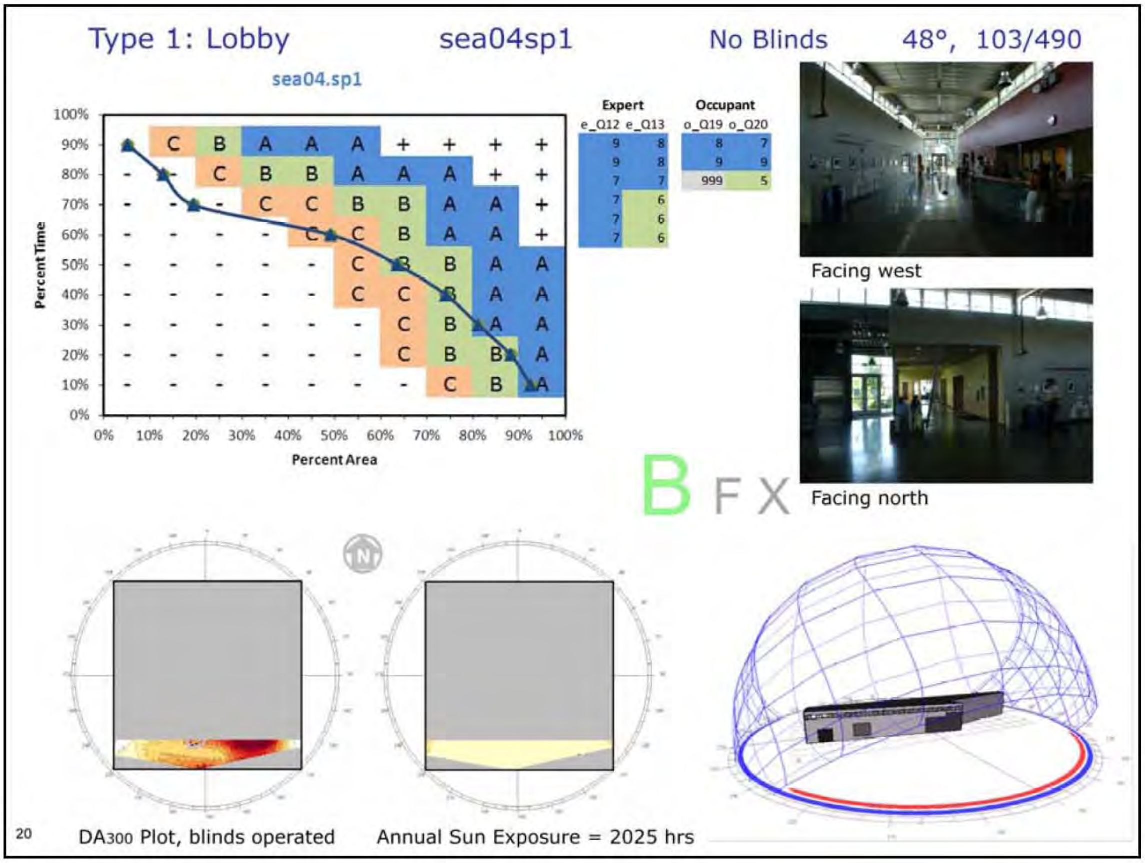
Elementary school classroom in Seattle. South facing view and high windows with light shelf. Second floor, with small monitor to north. No occupant



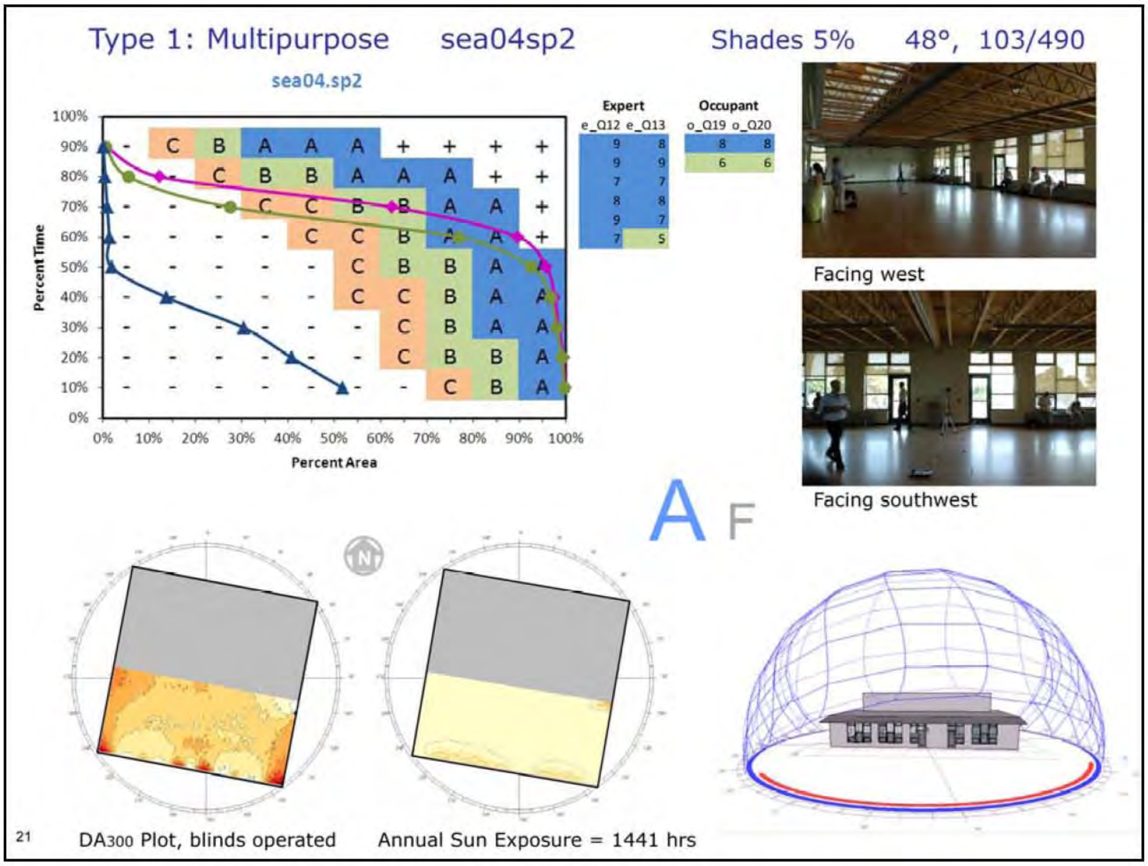
South facing college classroom in Seattle. Incorrectly modeled without exterior shading. Annual plot under predicts occupant assessment. Likely due



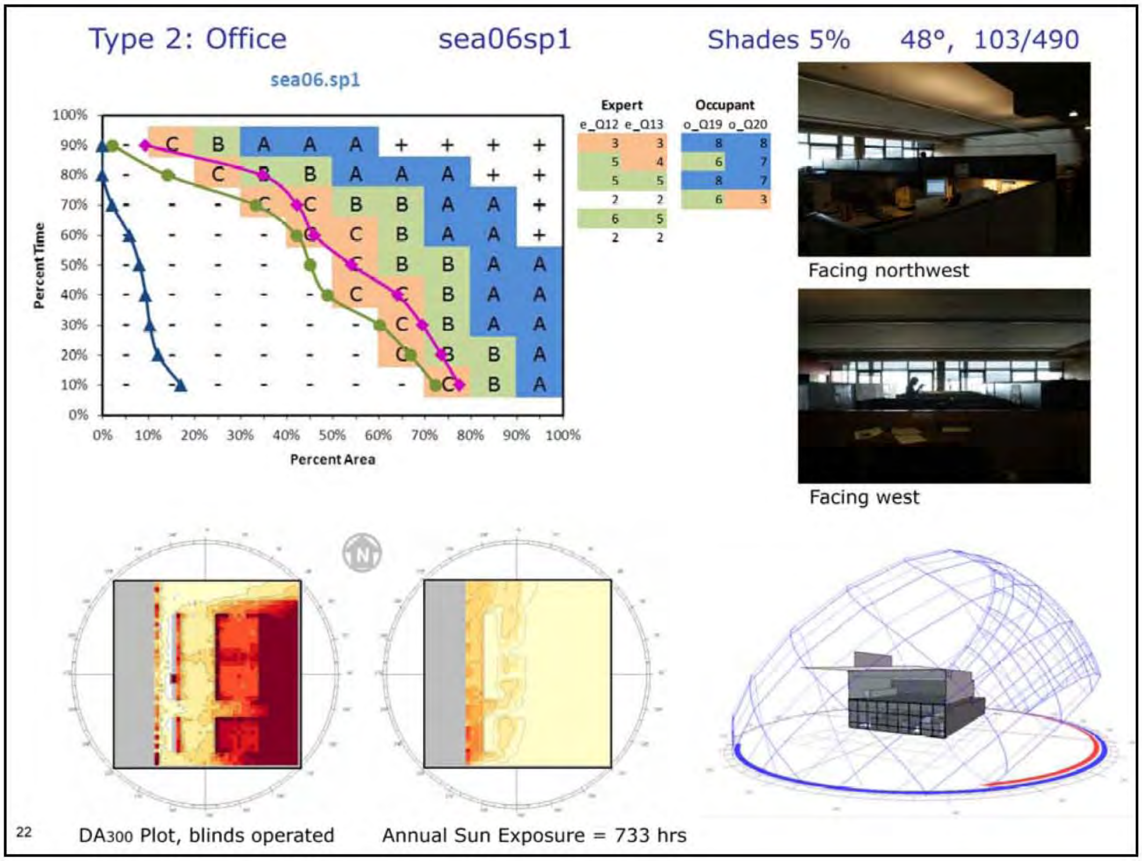
Lobby area at base of four story atrium with monitors. Annual plots under



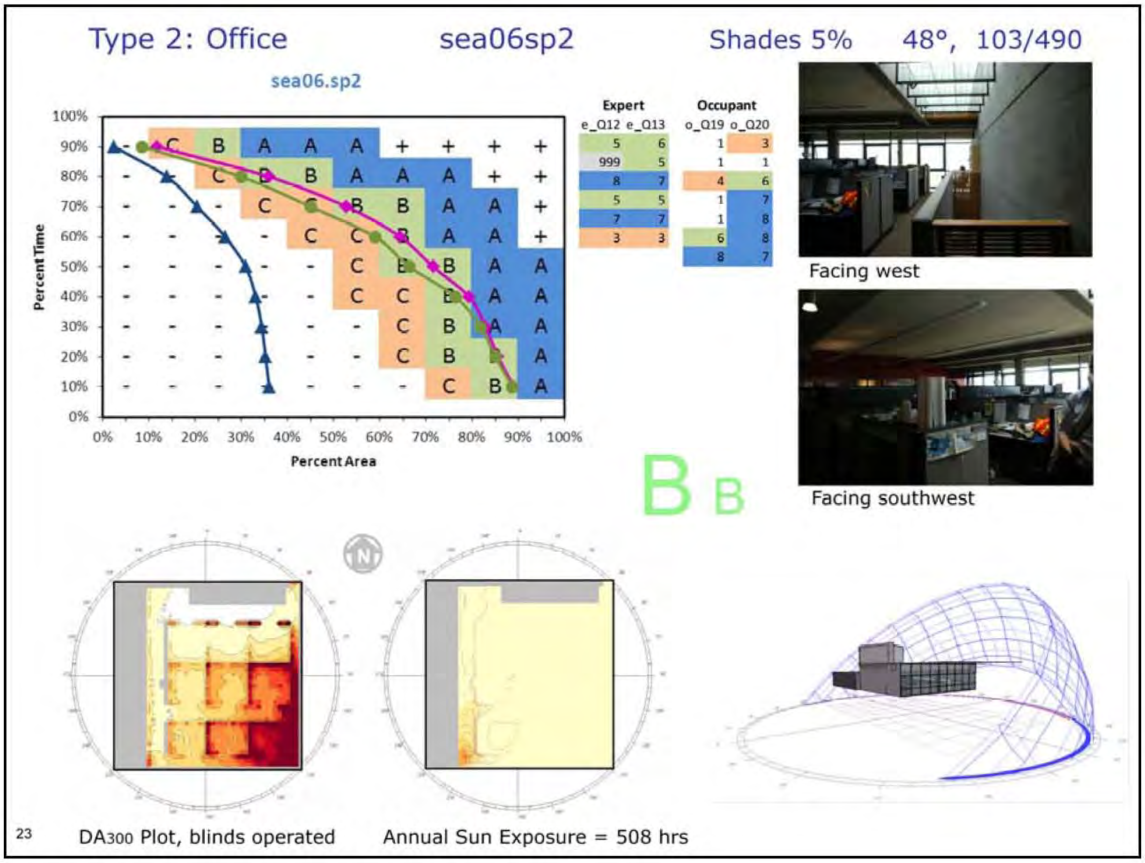
Community center lobby in Seattle, with high north and south clear clerestories. Annual plots under predict, especially at more than 50% of time or



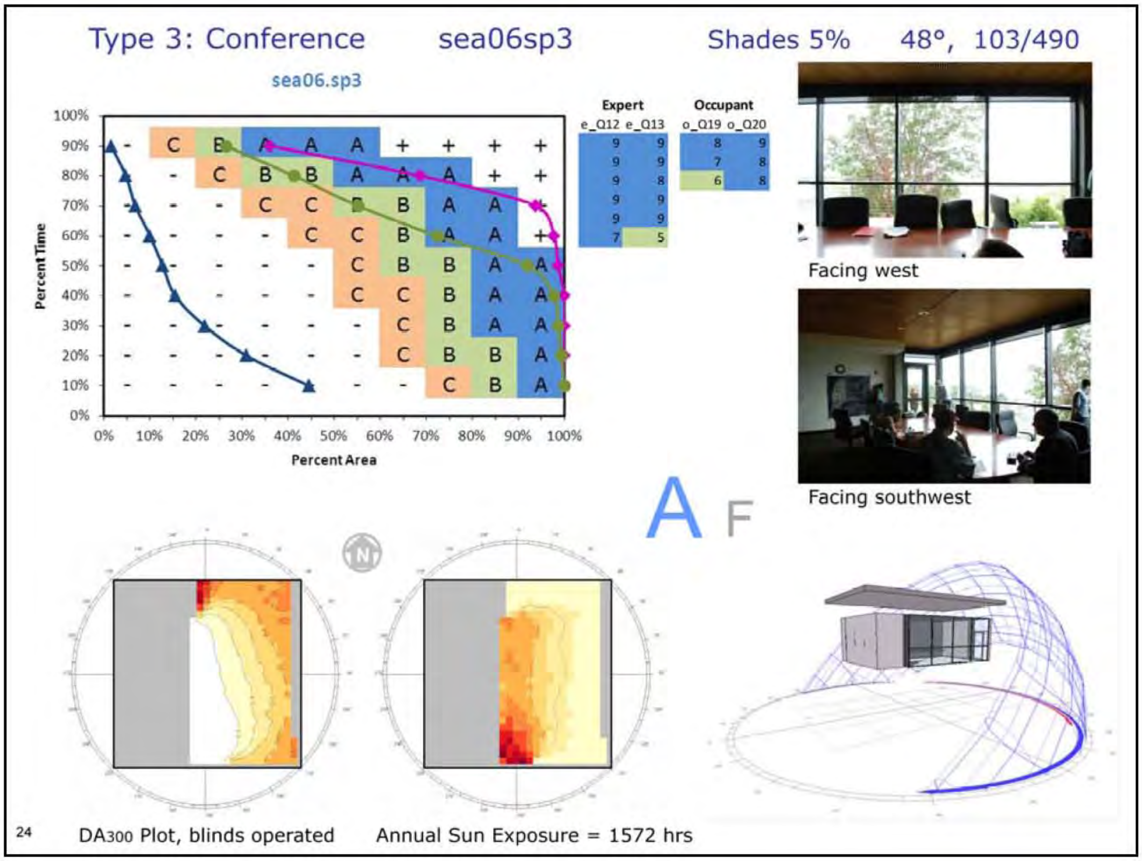
Community center multipurpose room in Seattle, facing SSW with monitors to north. Annual plots under predict at less than 70% of area or more than 70%



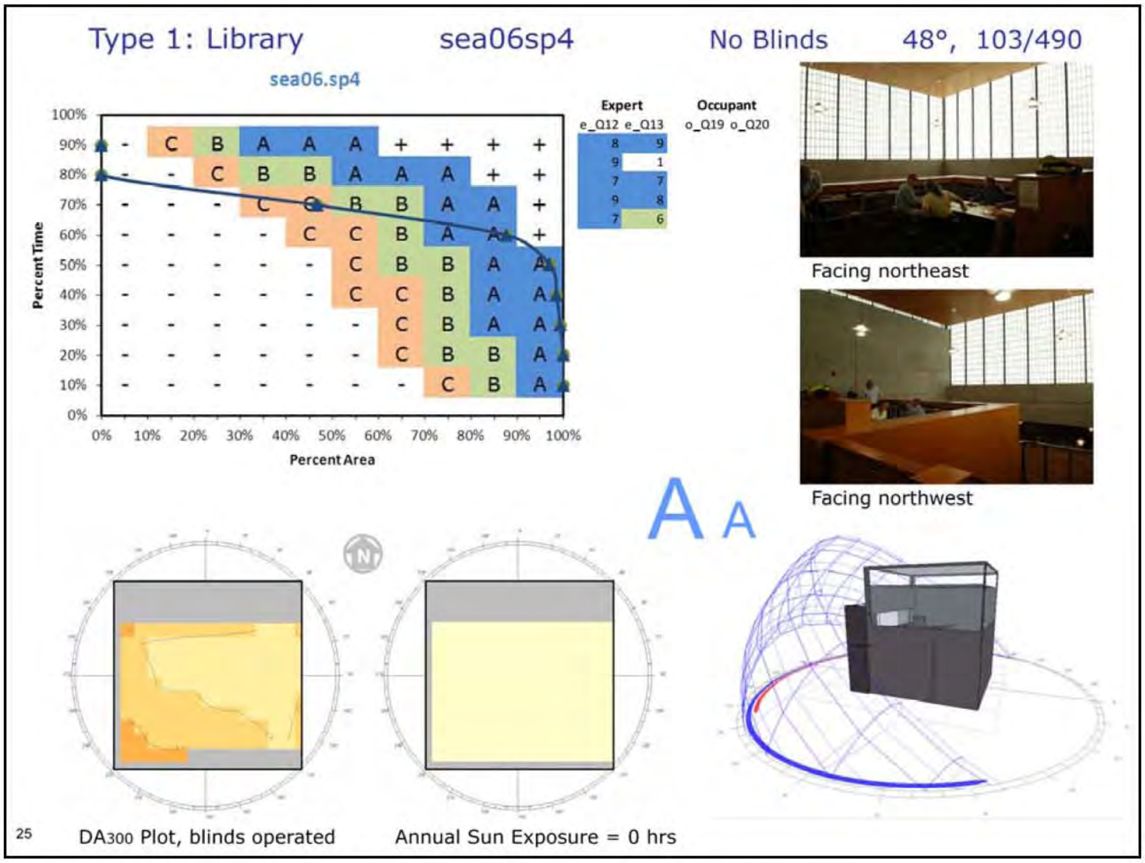
East facing office in Seattle with ‘borrowed light’ from monitor on floor above.



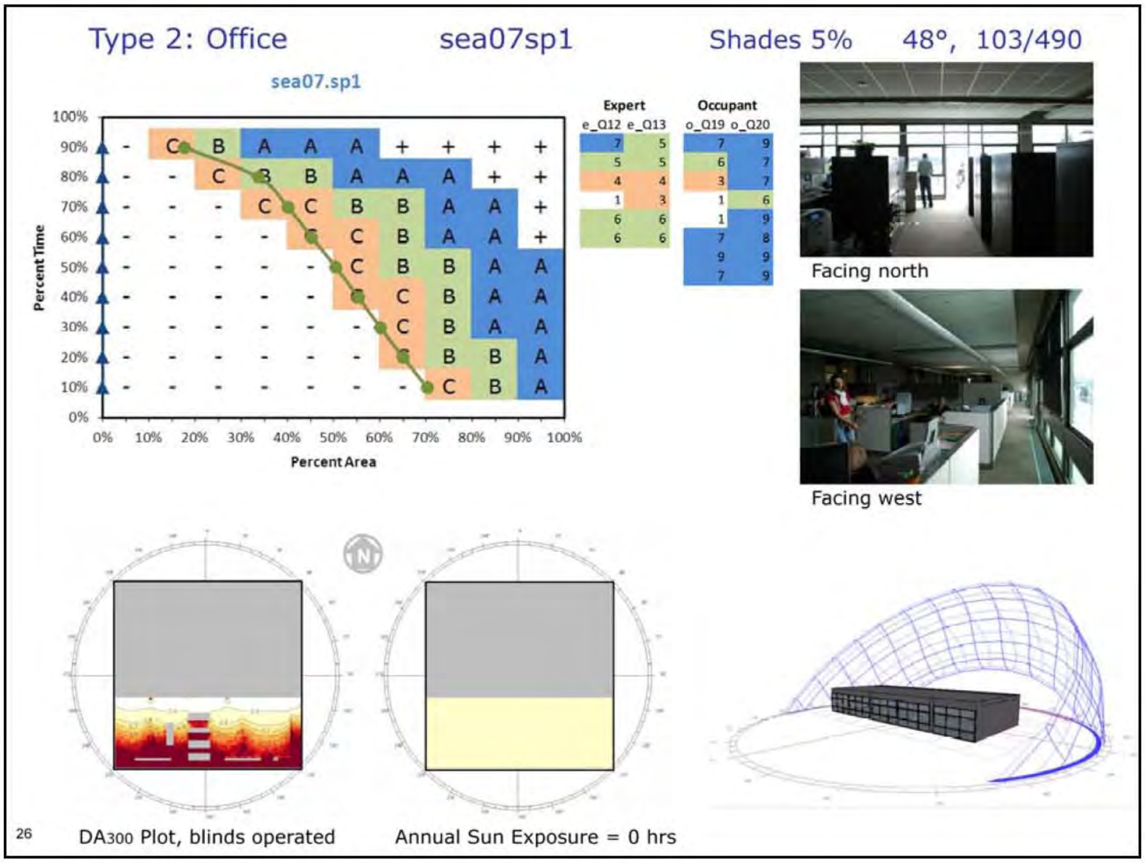
East facing offices in Seattle with monitors to north. High cubical partitions



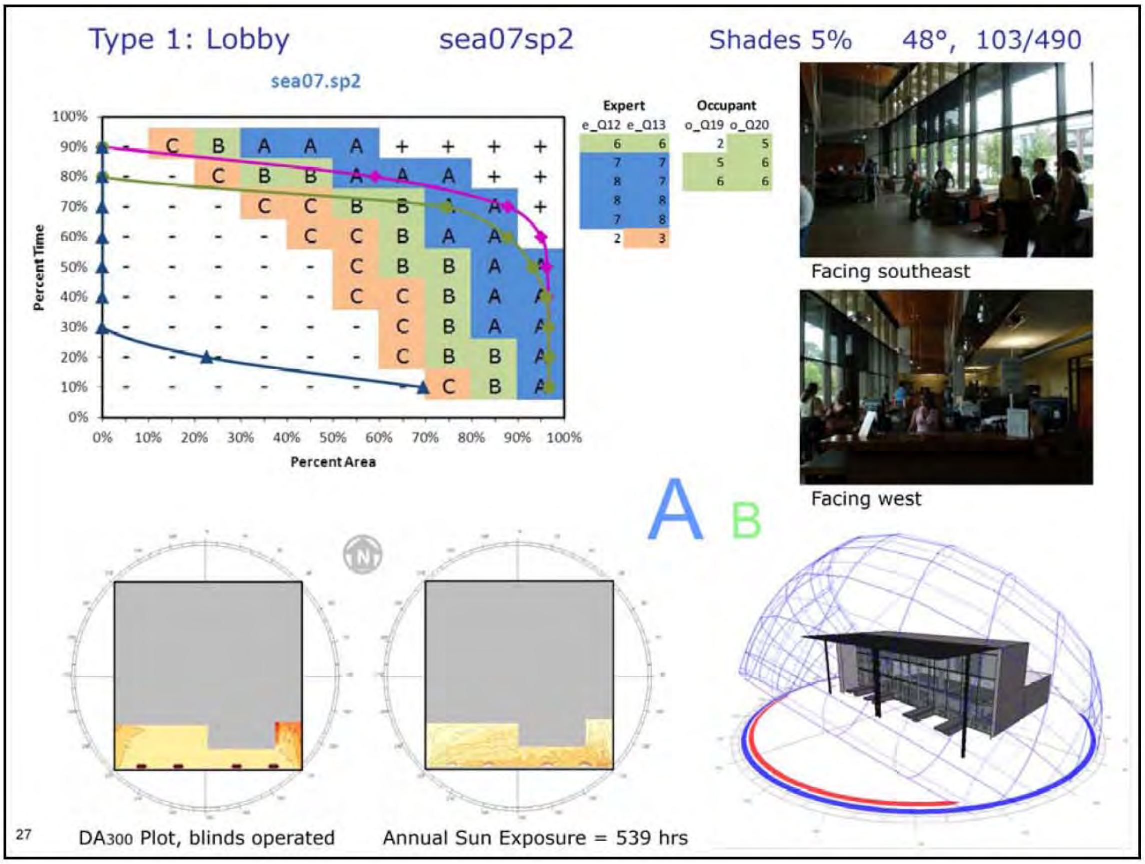
West facing conference room in Seattle, looking out to landscape. Annual plot



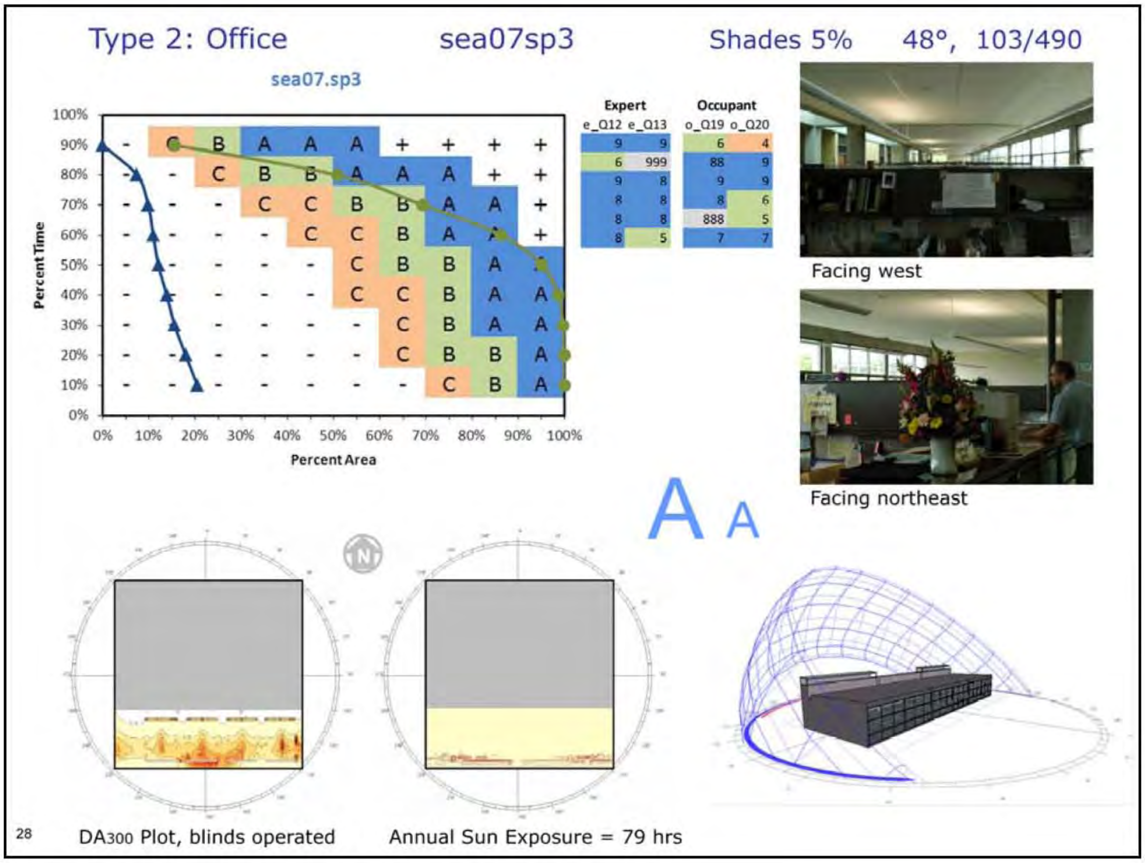
Interior library with high diffuse panels on four sides. Most uniformly illuminated space in study group. No occupant assessments. Annual plots correctly



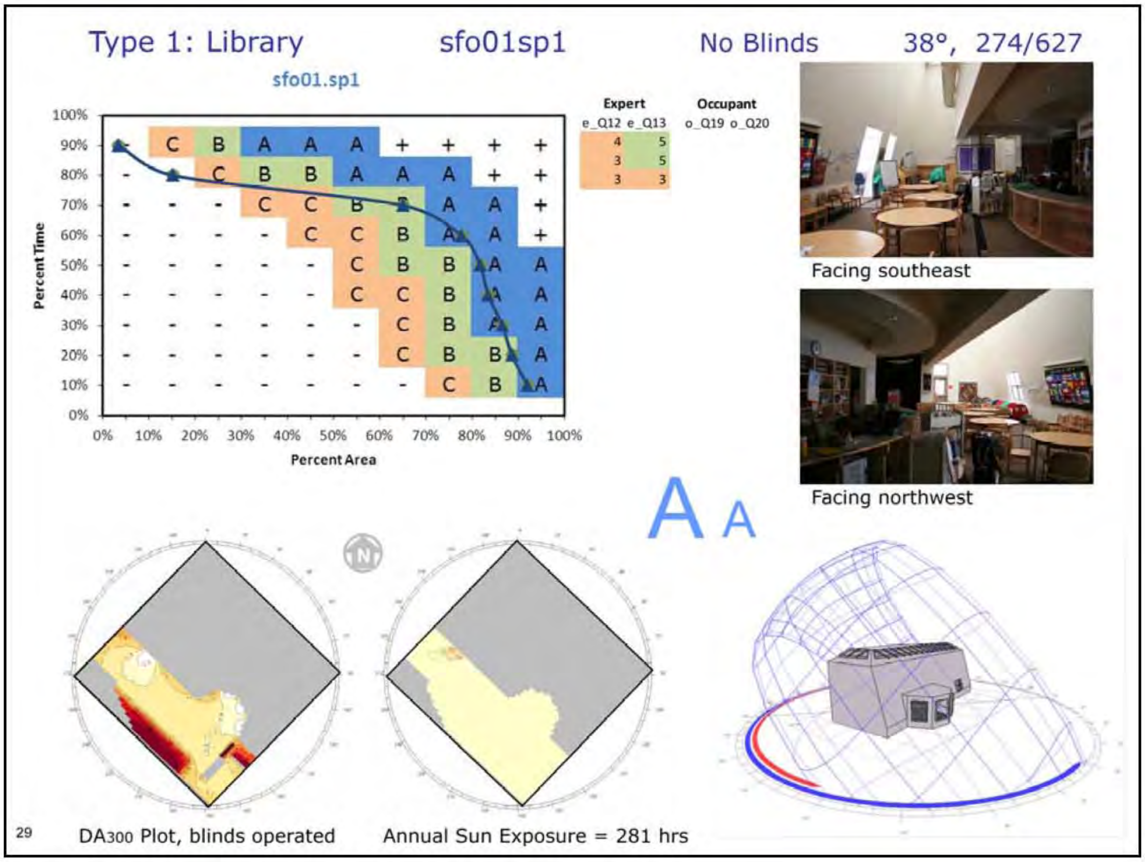
North facing offices along Seattle waterfront. Annual plot greatly under predicts



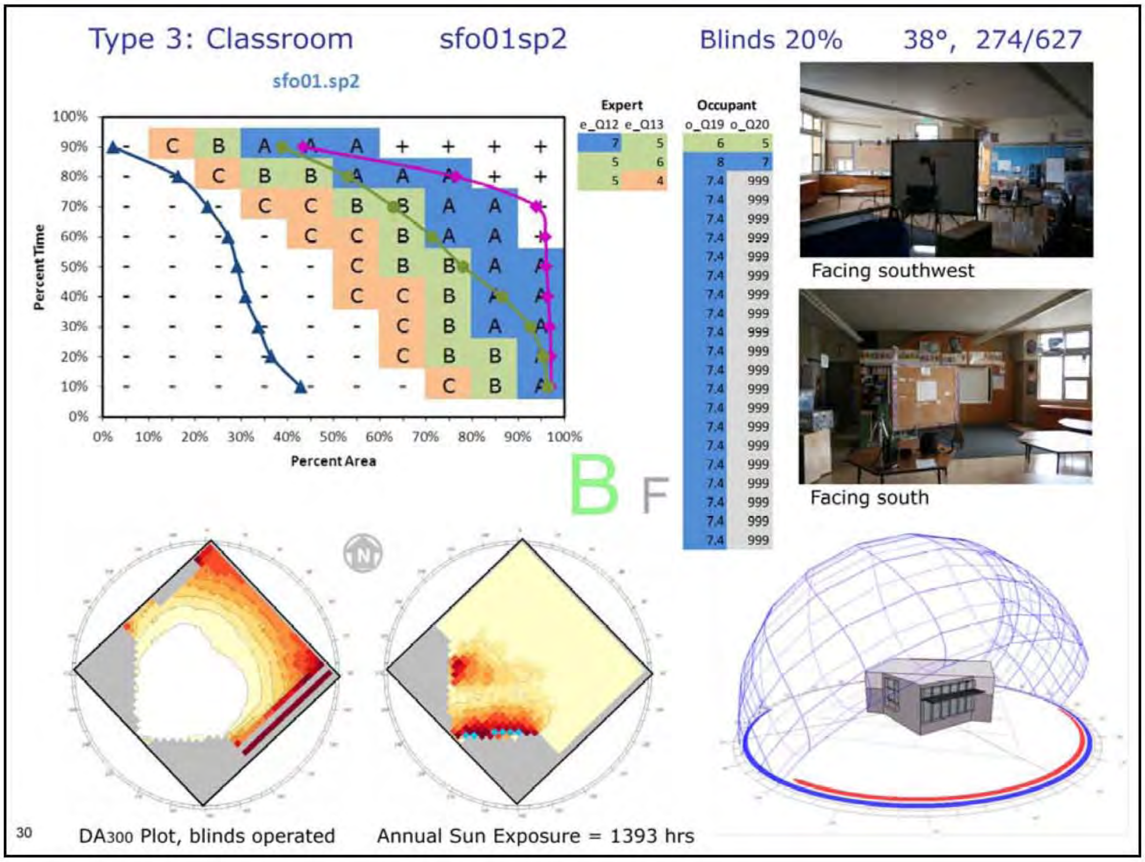
South facing lobby in Seattle with some shading and high tinted glass. Silhouetted views looking out of window. Annual plot overpredicts occupant



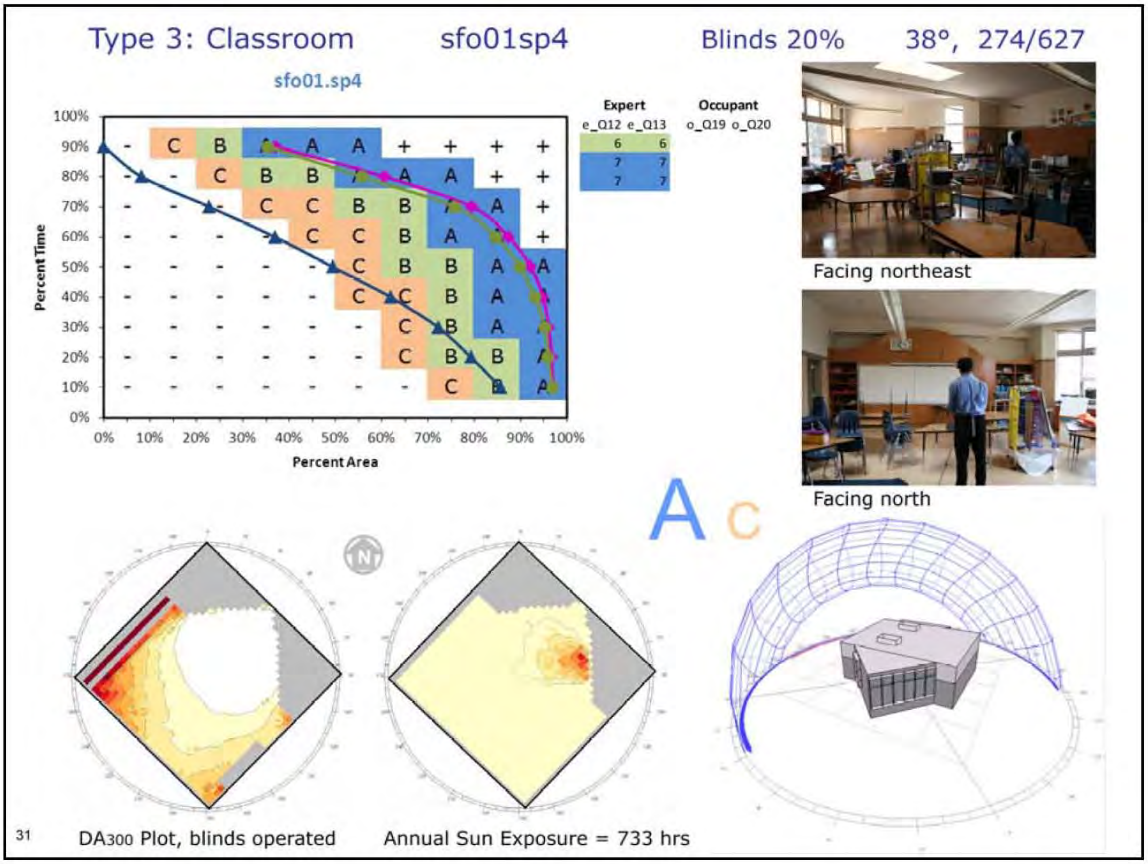
North facing offices on Seattle waterfront, with monitors along back wall.



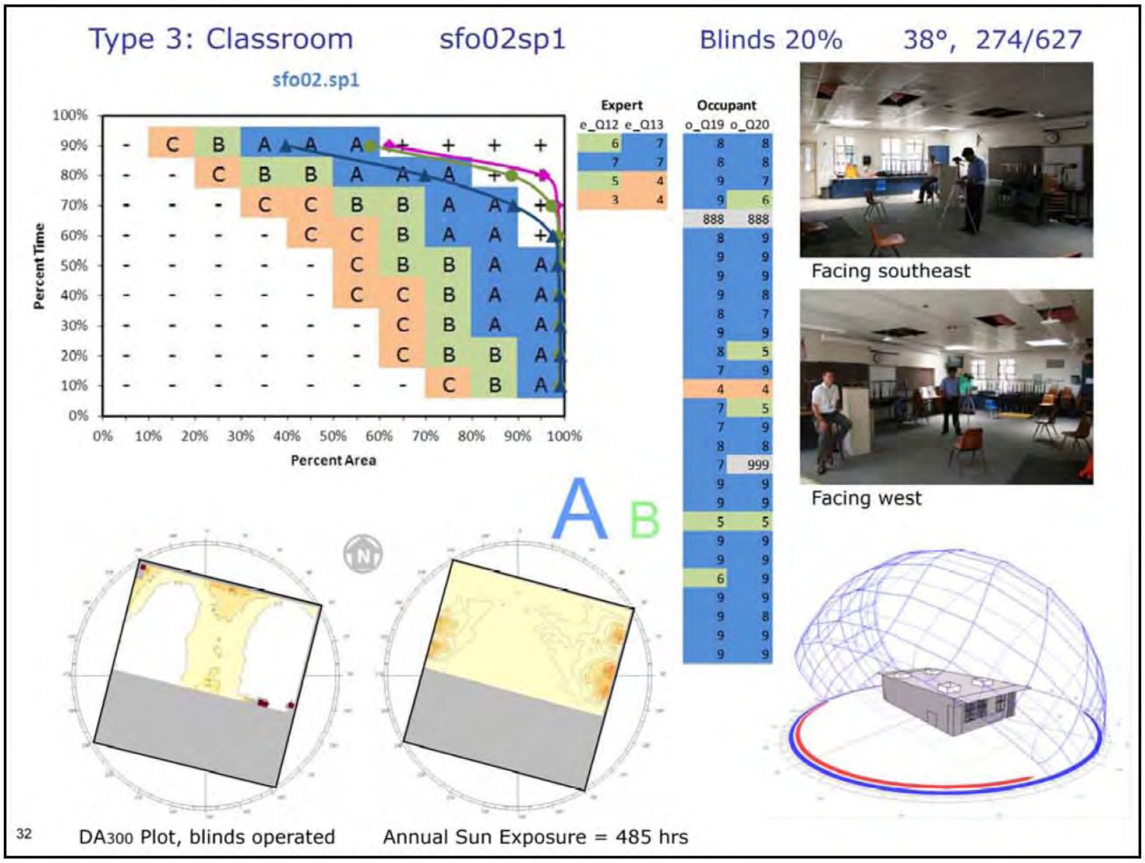
Elementary school library with overhead translucent panels and N-E facing glass-block reading or discussion bay. No occupant assessment available.



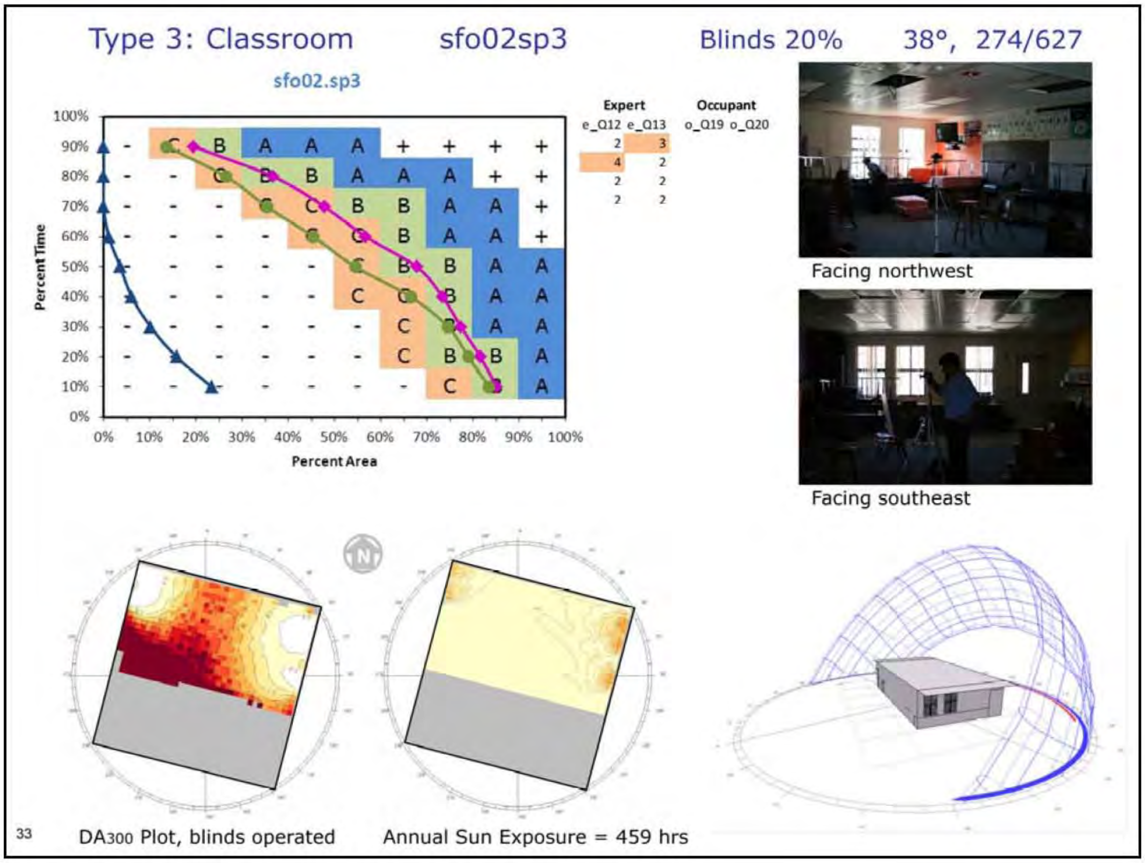
Elementary classroom with south facing window and some shading of view window. Student assessment by class vote, highly positive. Annual plot



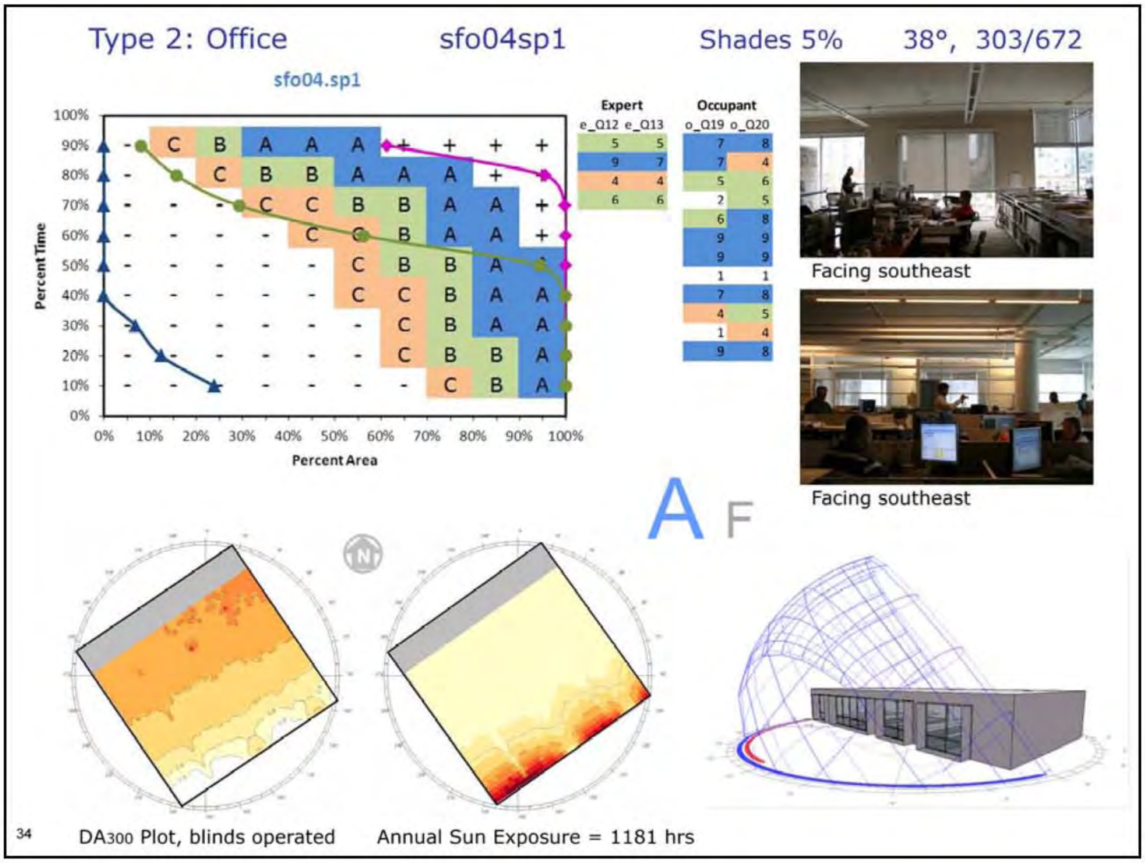
Elementary classroom with north facing window and two low Tvis skylights. No occupant assessment. Annual plot predicts expert assessment. Lights on



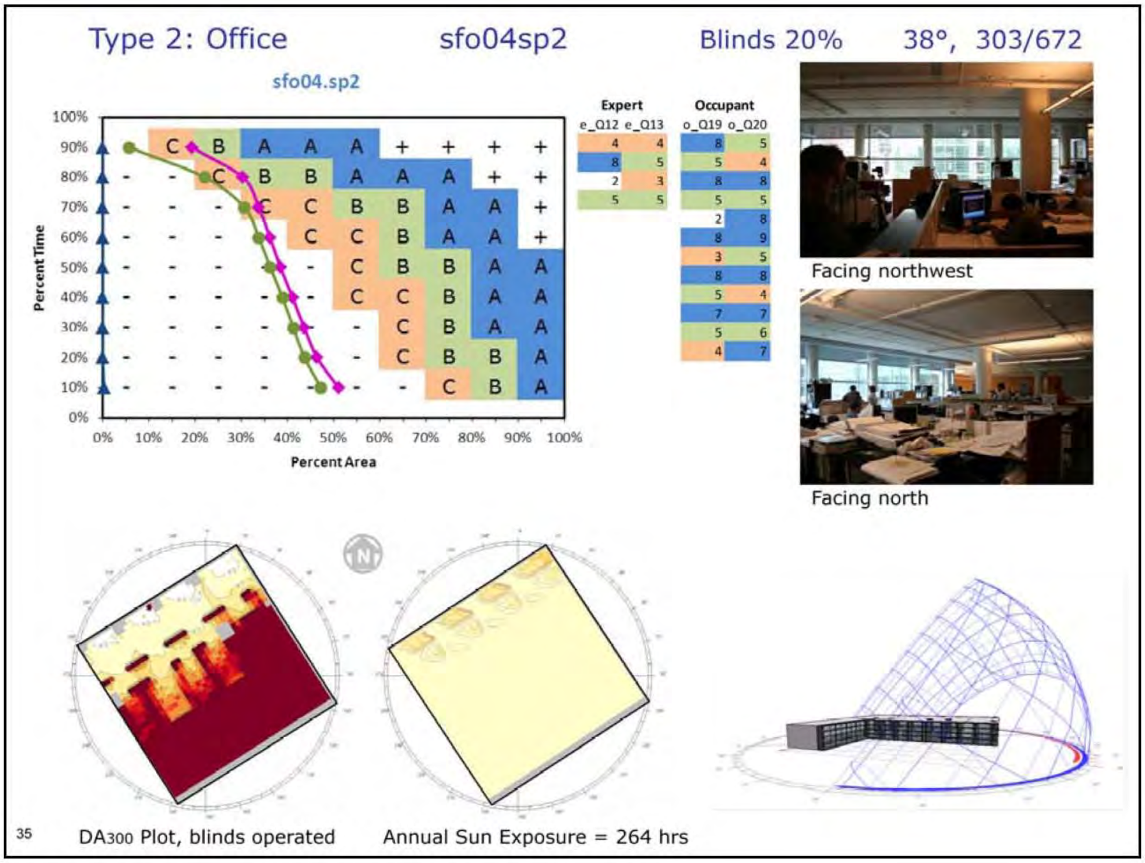
Portable classroom with four 4'x4' skylights added. Annual plot predicts high



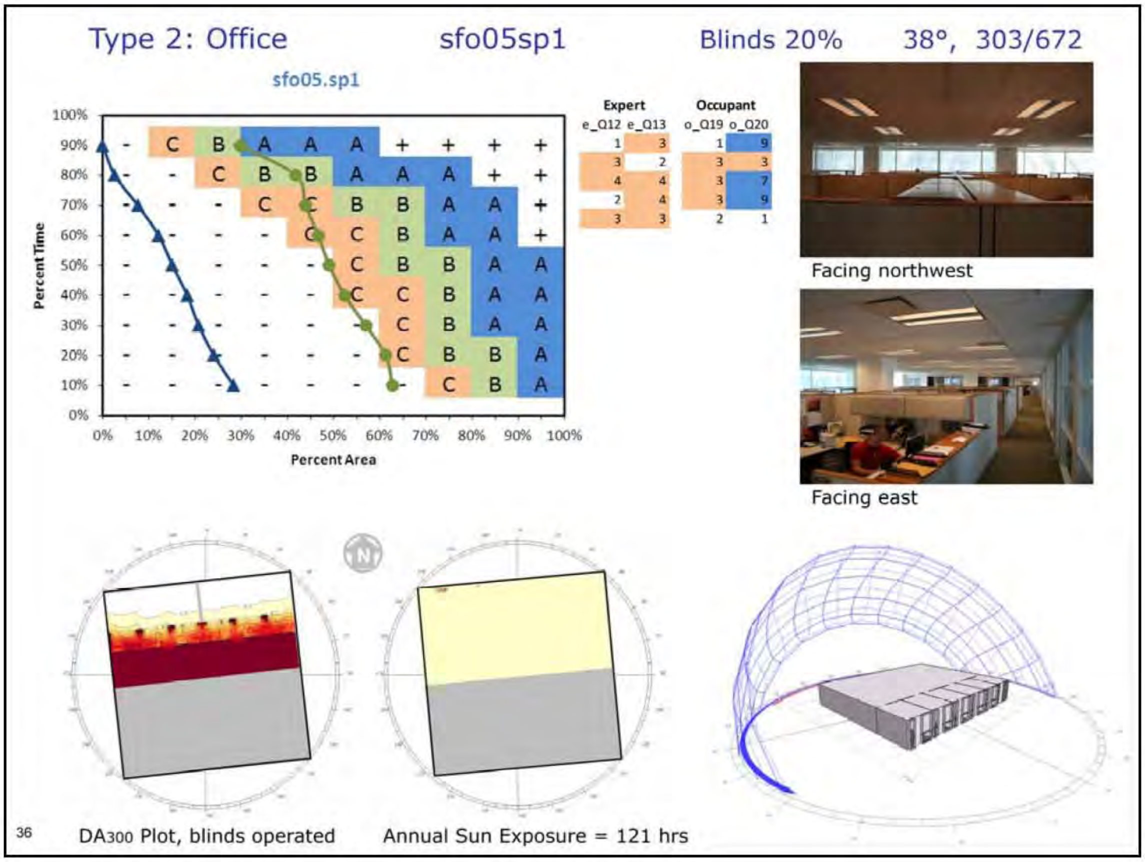
Portable classroom, identical to previous, but with no skylights. No occupant



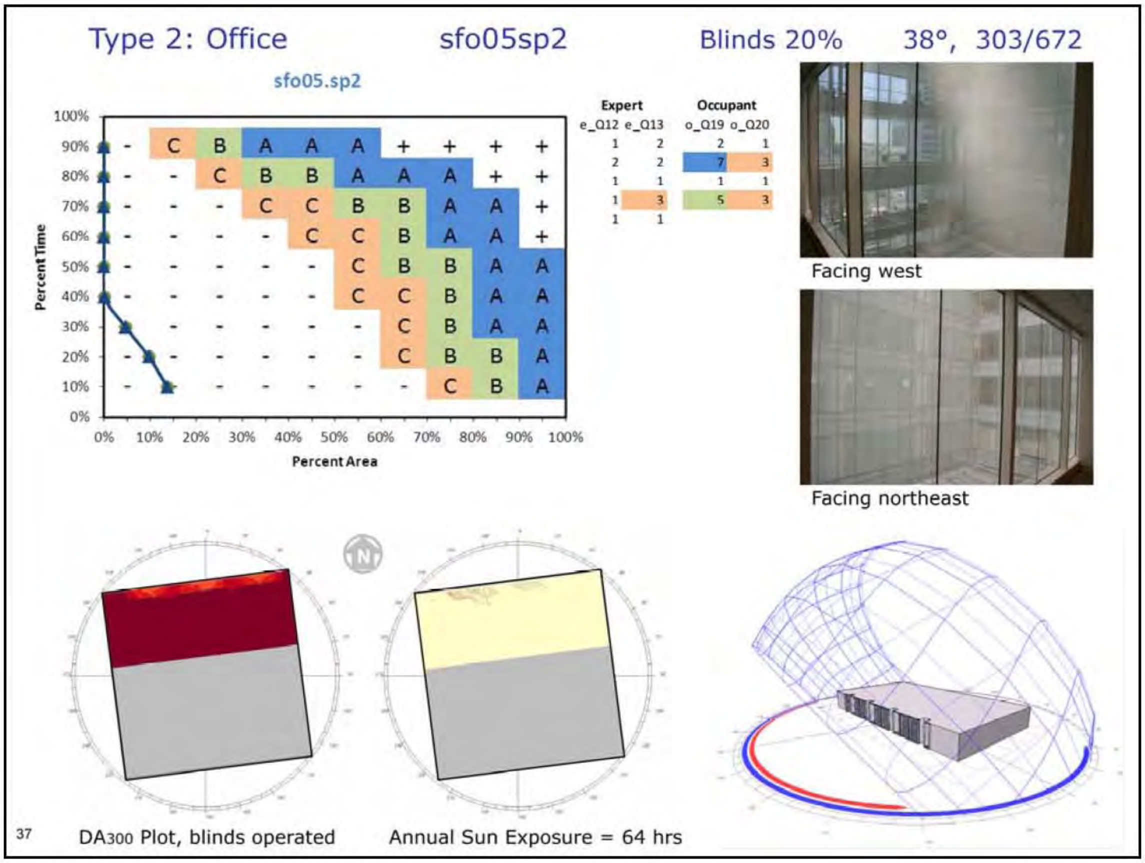
South facing offices in San Francisco. Highly dependant on shade operation



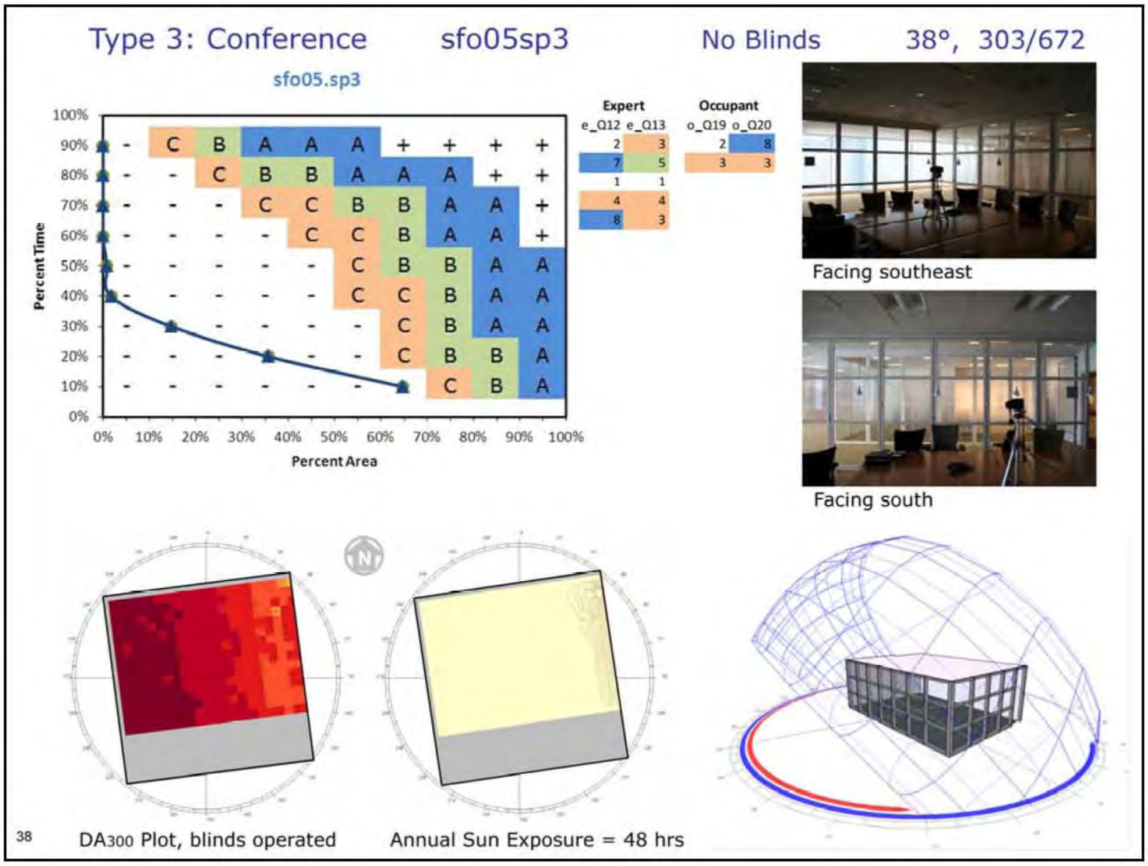
North-west facing offices in San Francisco. Annual plot <u>greatly</u> underpredicts



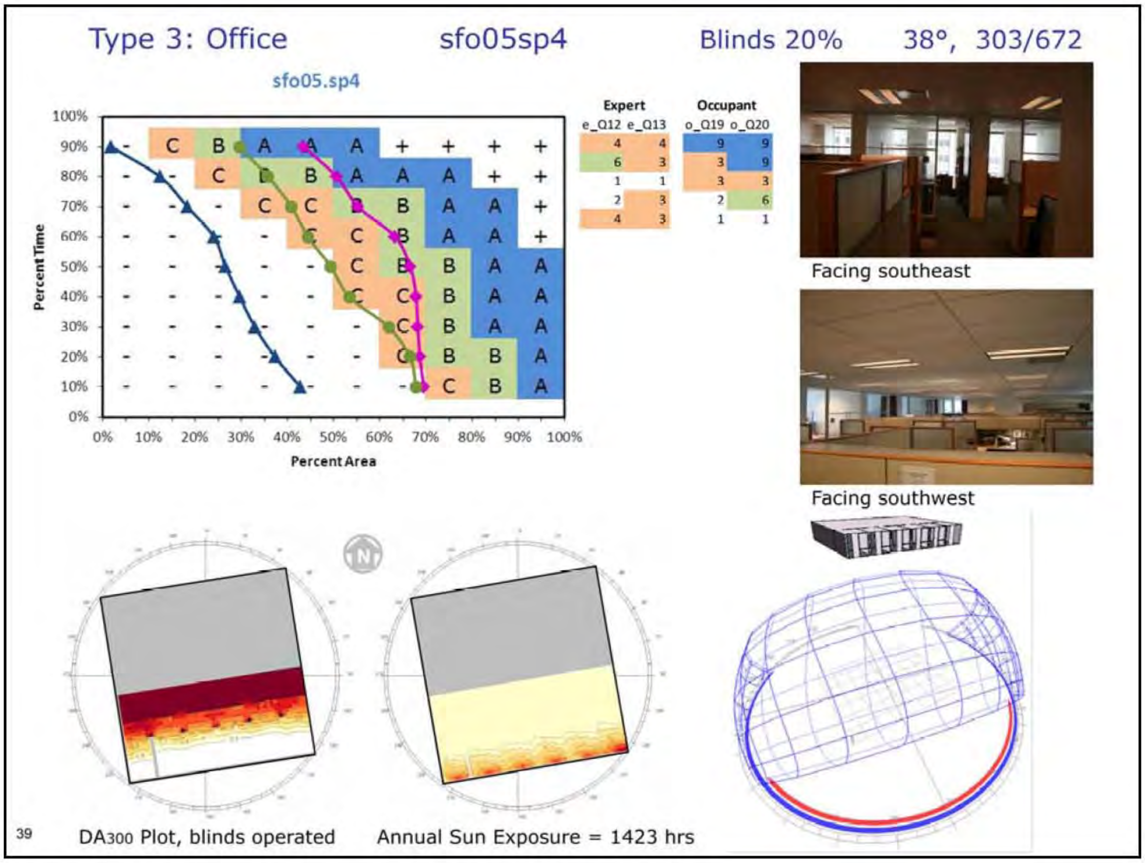
North facing offices in San Francisco. Private offices at perimeter with glass partitions to 5' high cubicals. Annual plot with blinds operated predicts occupant response on Q19 (I can work with ll electric lights off)., but underpredicts acceptance of daylight sufficiency (Q20). View to north may



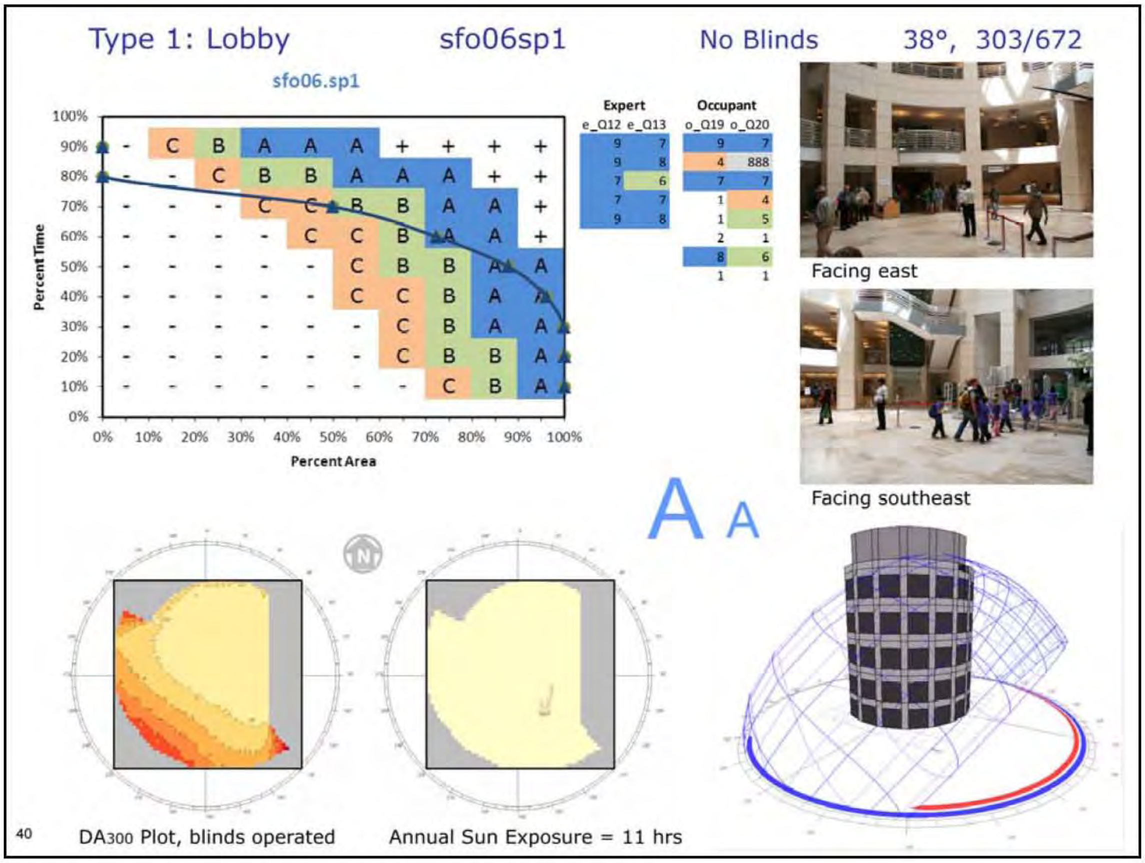
South facing cubical offices into atrium with fritted windows. Annual plot



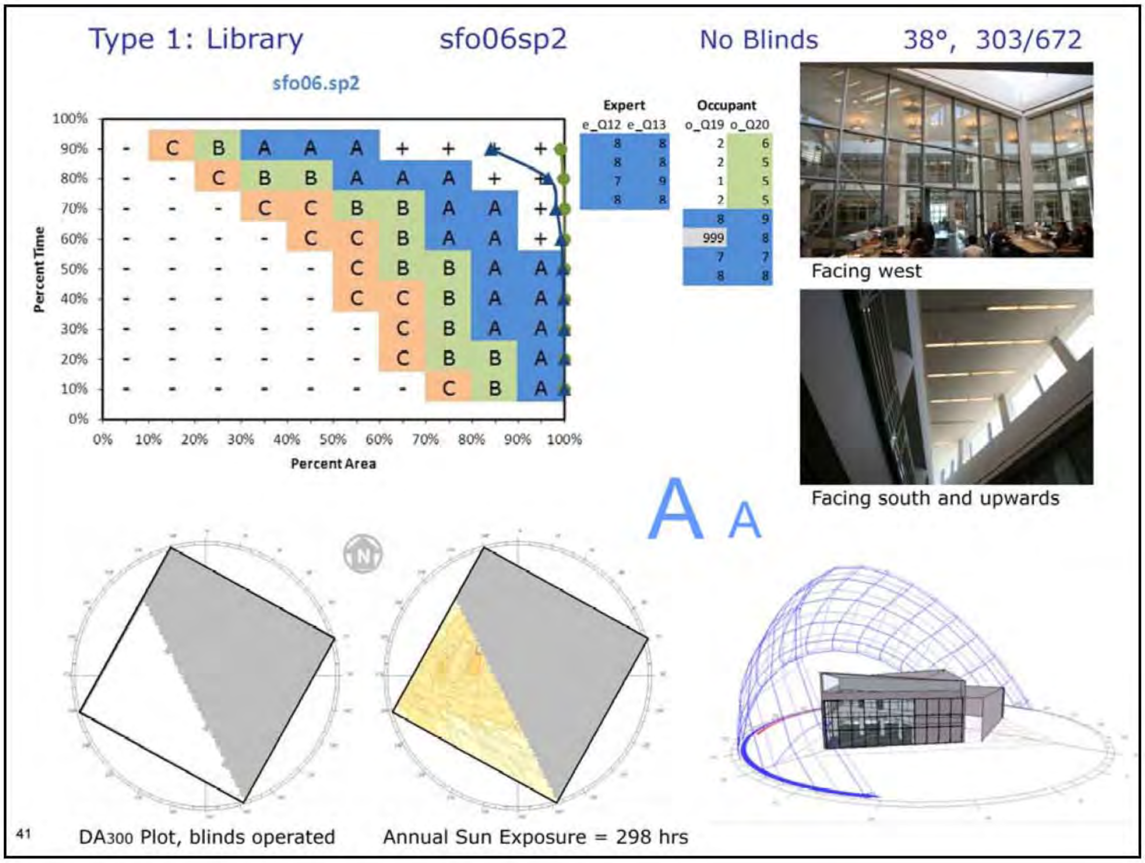
Conference room with “borrowed daylight” from nearby atrium. Low levels of very uniform daylight. Annual plot under predicts both expert and occupant



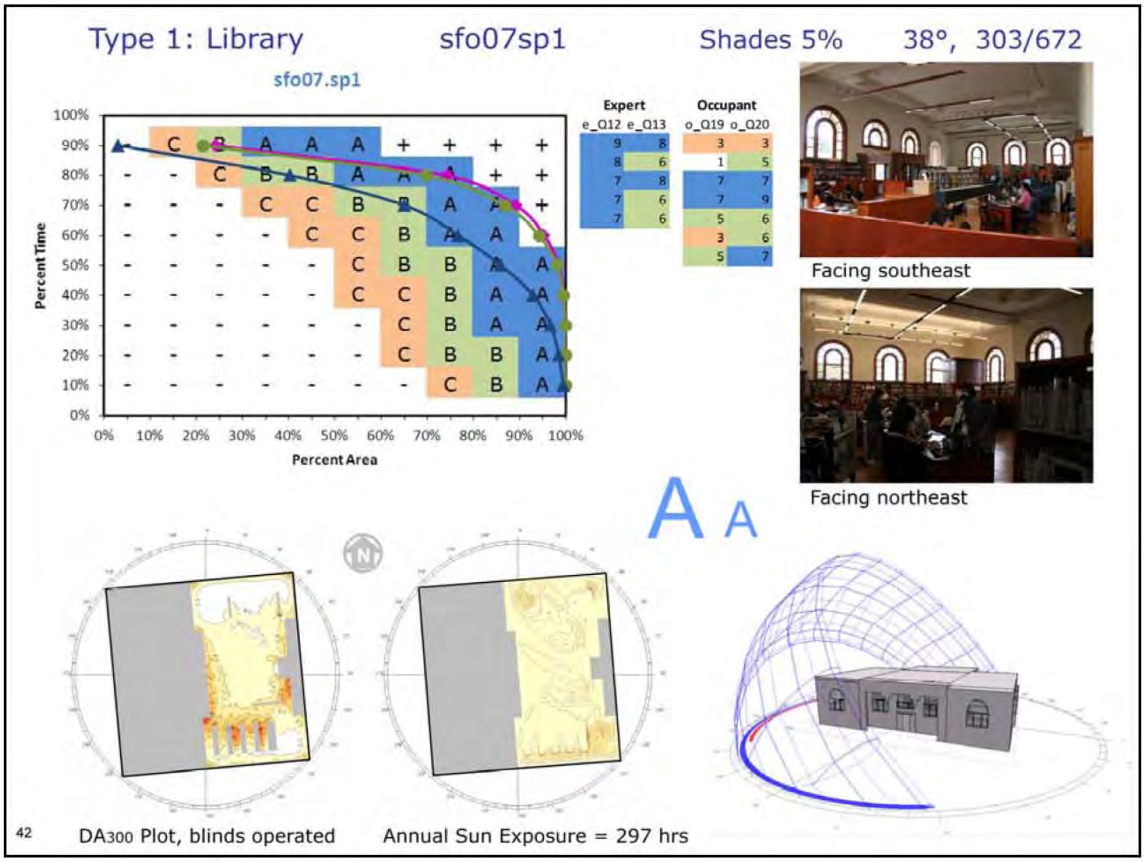
South facing offices in San Francisco. Private offices at perimeter with glass partitions to 5' high cubicals. Annual plot with blinds operated predicts



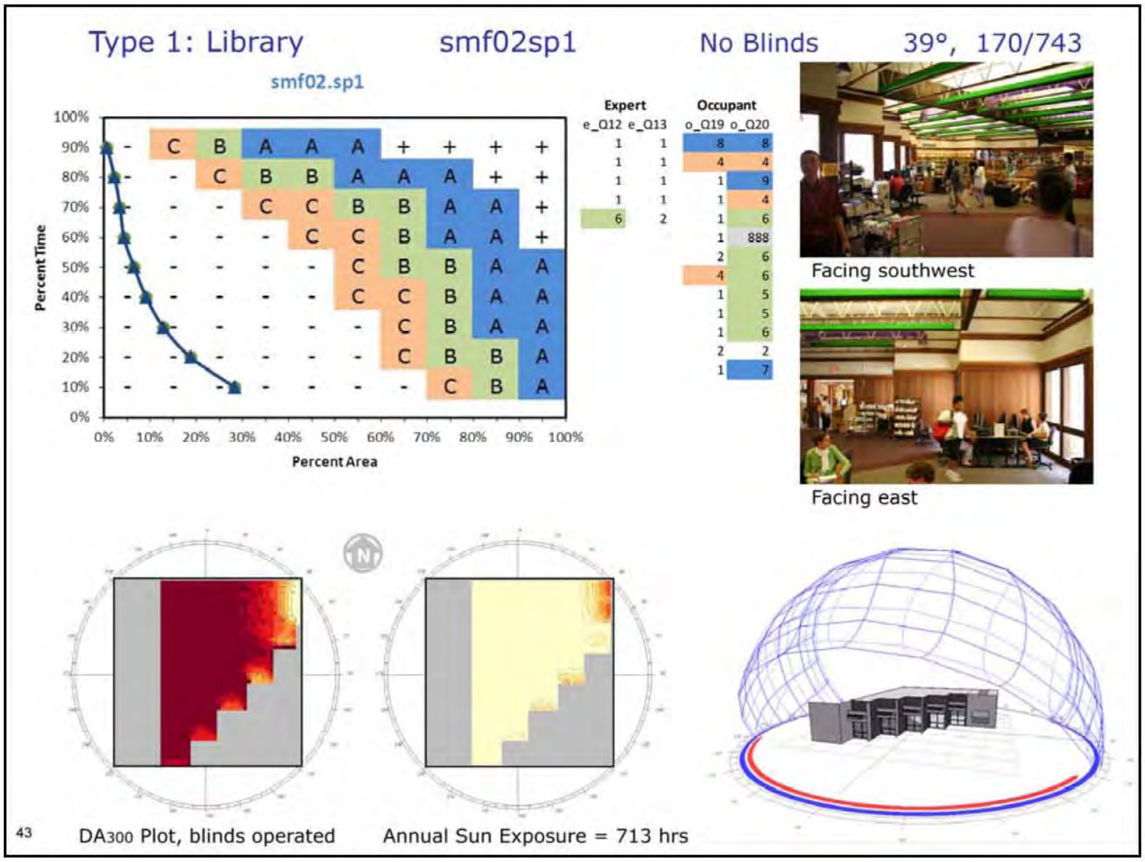
Modern lobby in San Francisco, with service counters at periphery. Annual



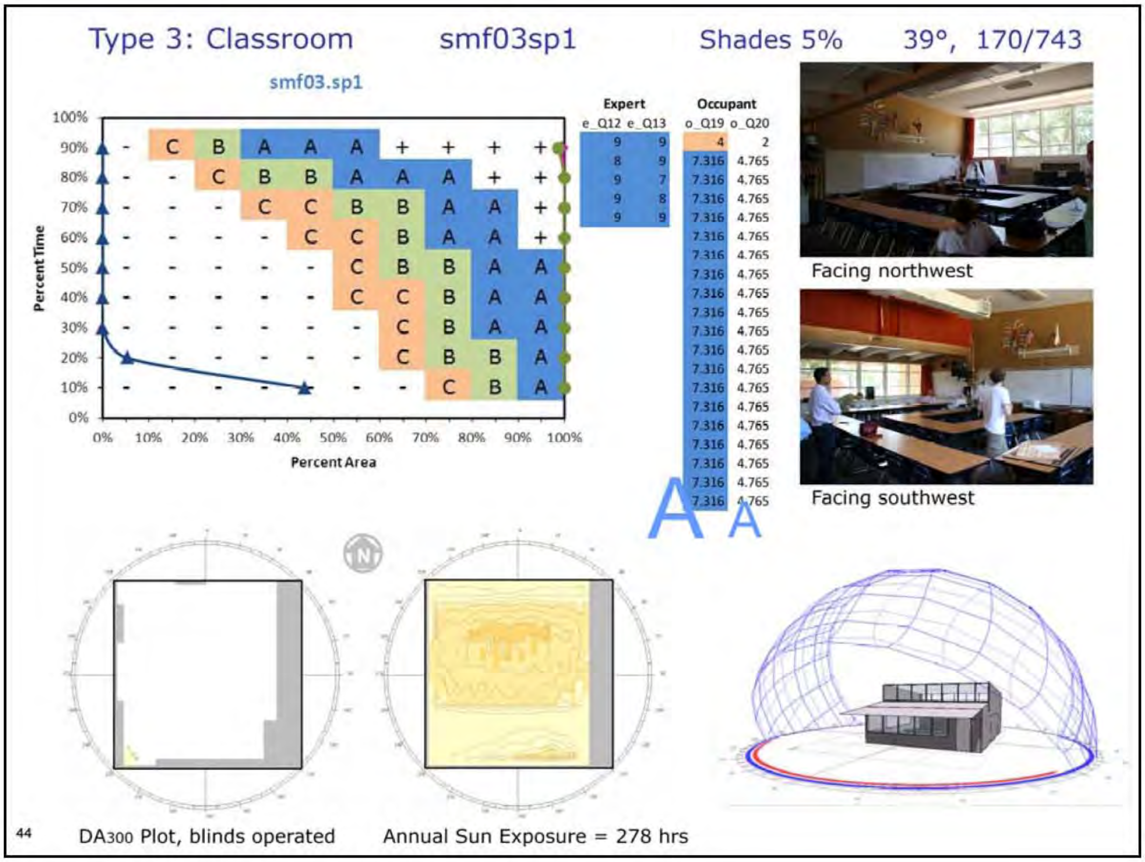
Modern library reading room in San Francisco. Odd geometry difficult to simulate correctly. Direct sunlight makes it down to reading tables. Occupant



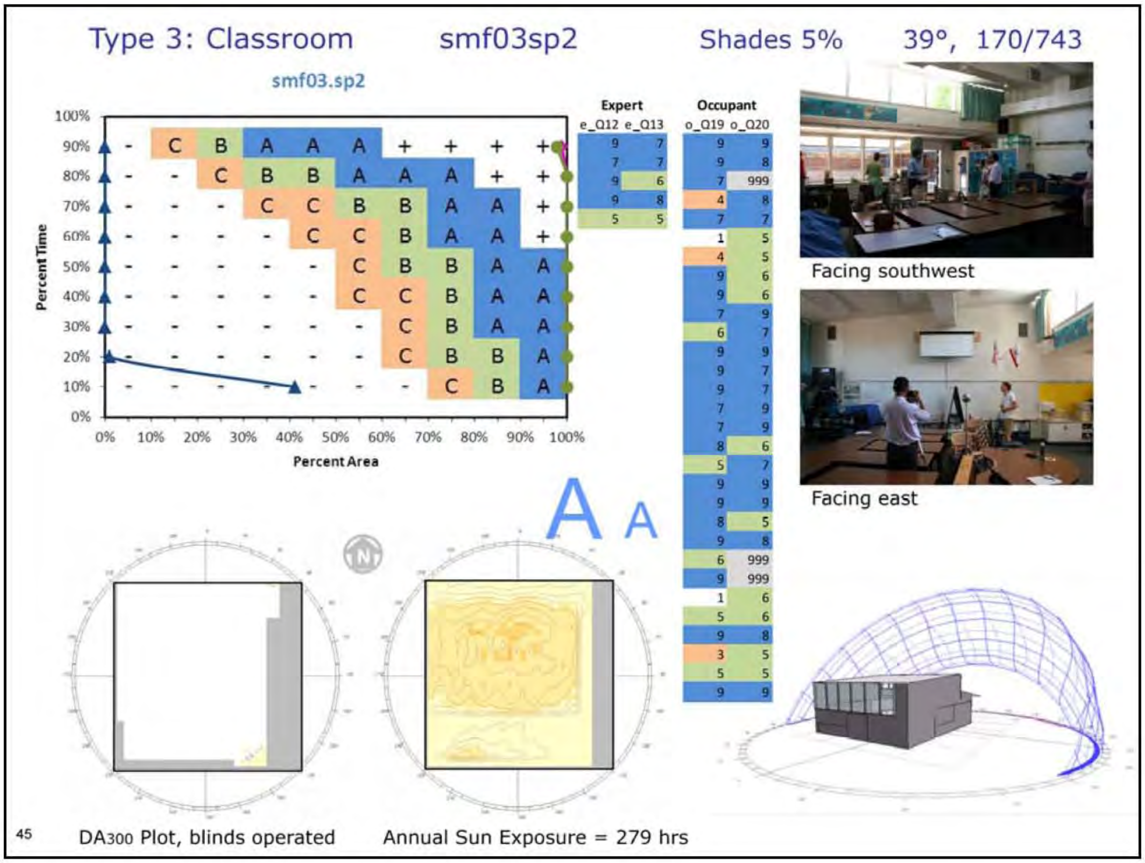
Classic early 19th century library in San Francisco, with high clear windows on four sides. Annual plot predicts higher ratings than received from occupants. Electric lights always left on, but library observed to be highly functional during



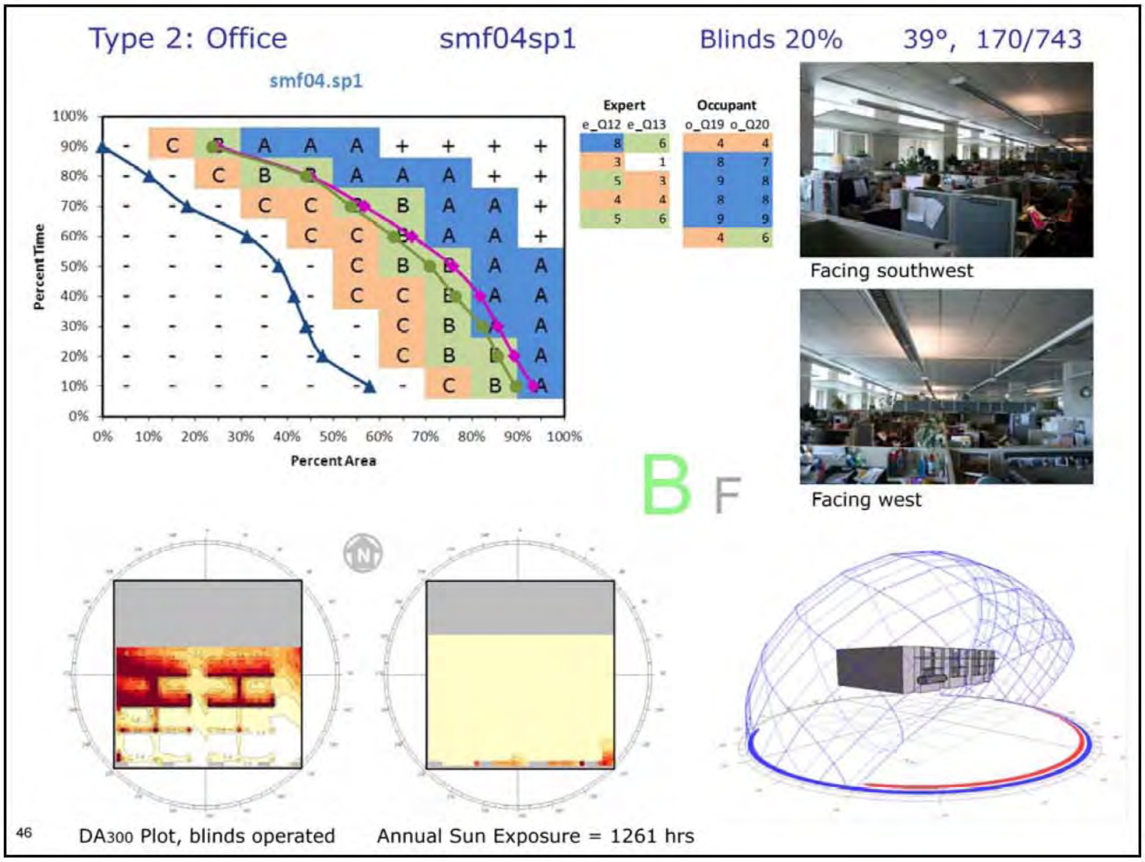
Library with well-shaded south windows, darkly tinted, with view to park. Occupants report they cannot work with all the electric lights off (Q19), but daylight sufficiency (Q20) is adequate. Pleasant view may contribute. Electric



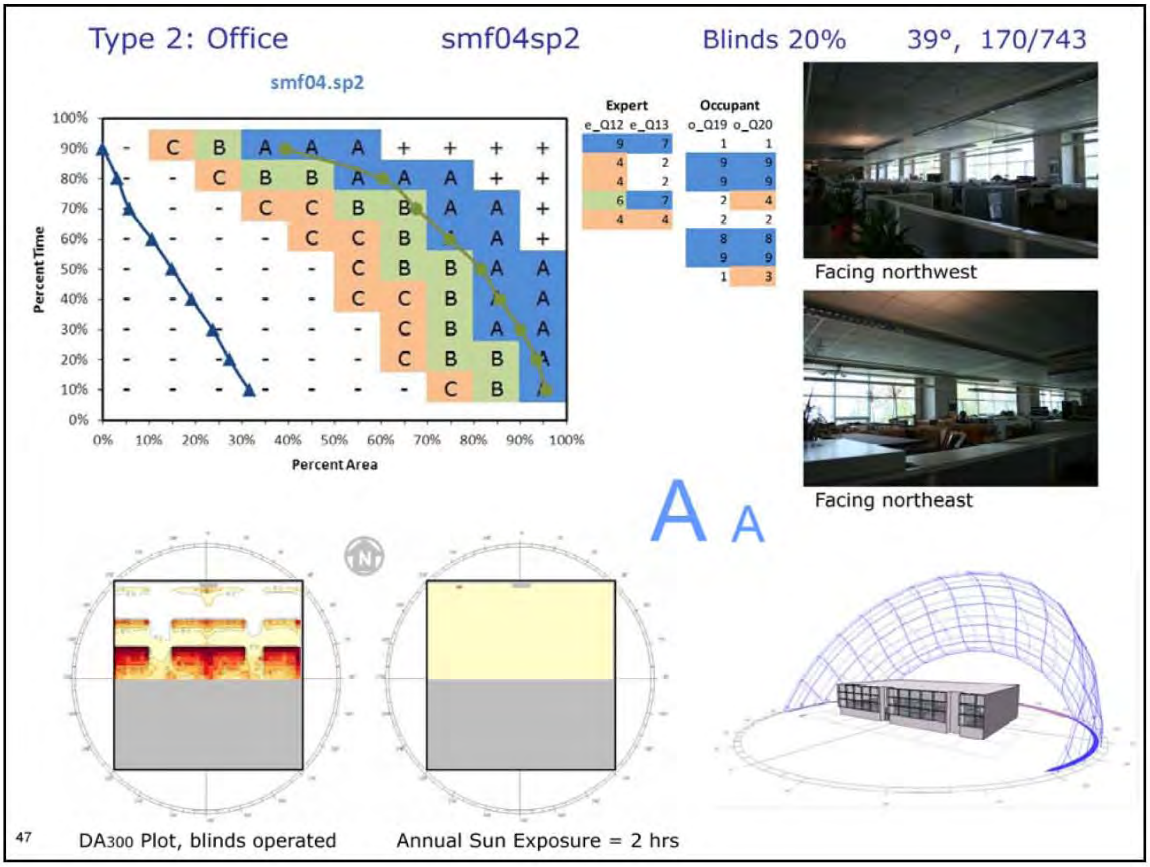
Older sixties style classroom, with extensive north and south windows and clerestories. Second grade students rate the classroom very high (via teacher led vote) , but annual plot might indicate high daylight levels are off the chart.



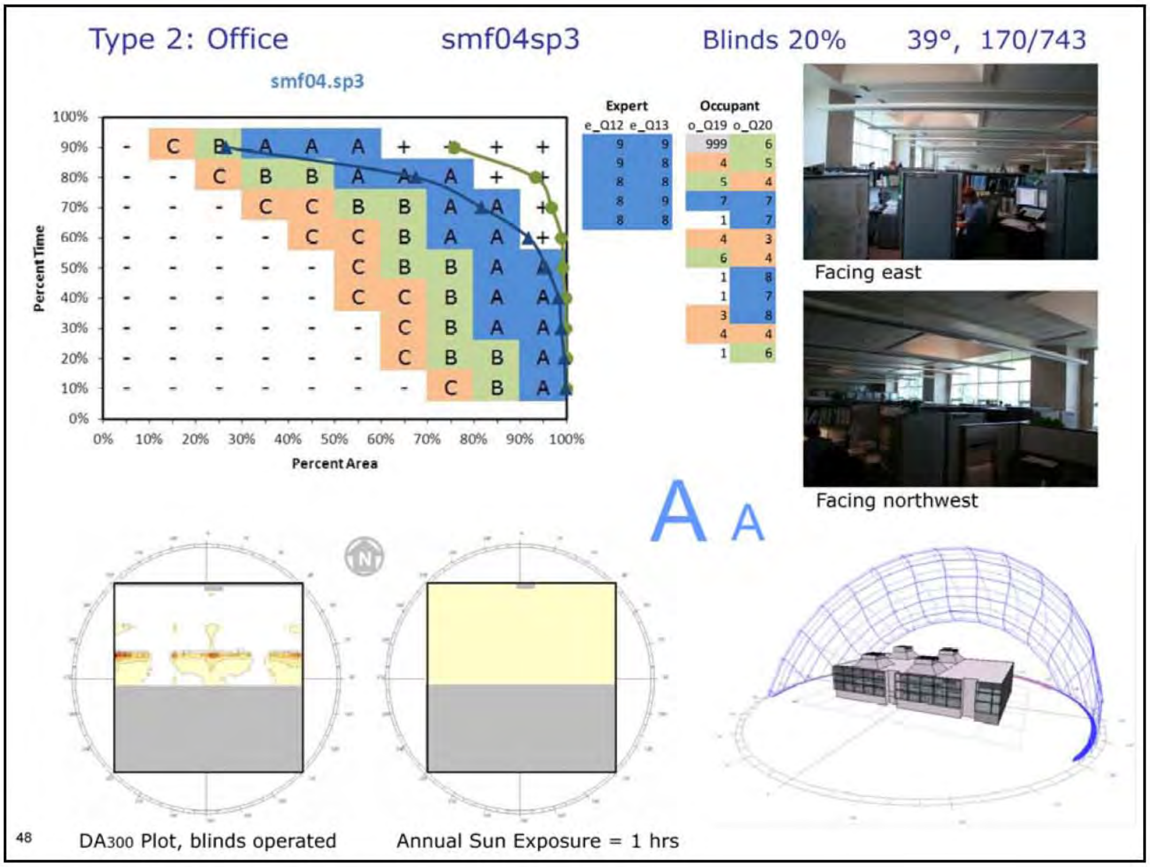
Older sixties style classroom, with extensive north and south windows and clerestories. Fifth grade students rate the classroom very high, but annual plot



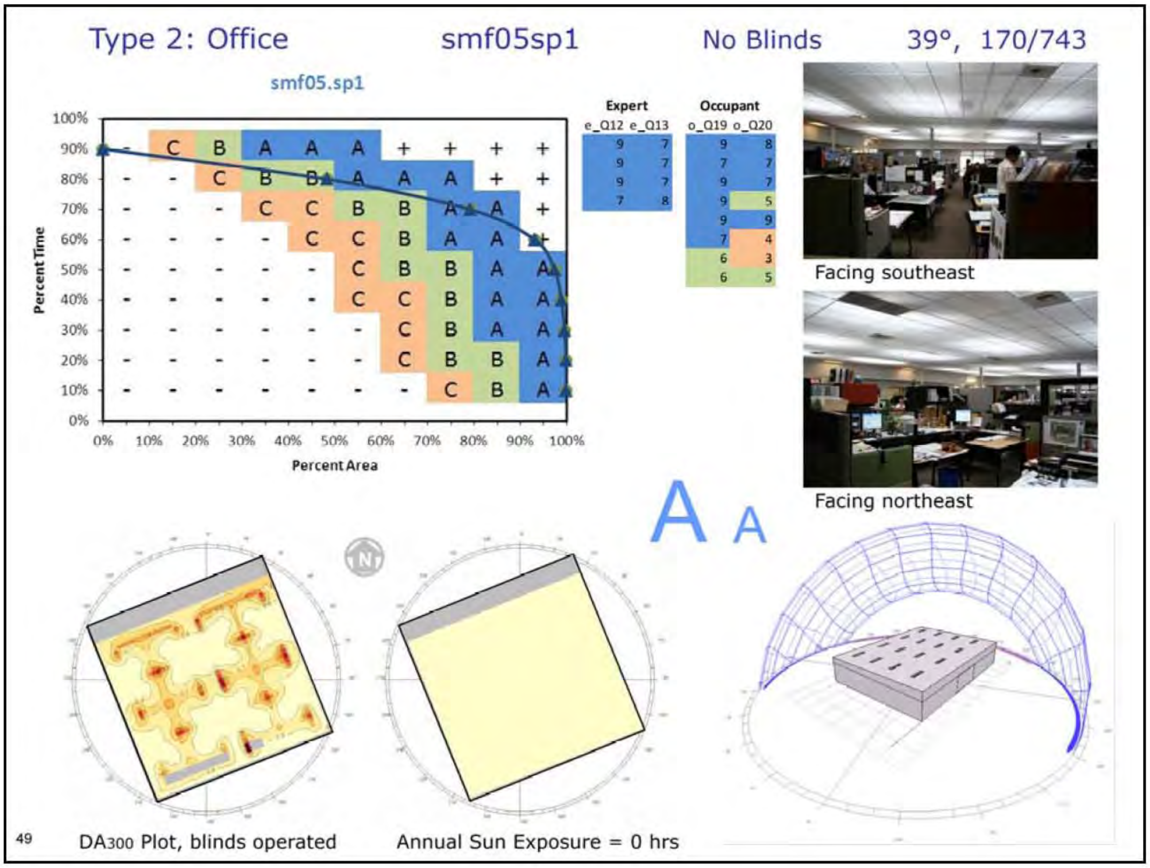
South facing office in Sacramento, well-shaded, with slightly translucent lightshelves. Annual plots slightly underpredict occupants and overpredict experts. Daylight less uniform than in 2 following northfacing offices in same



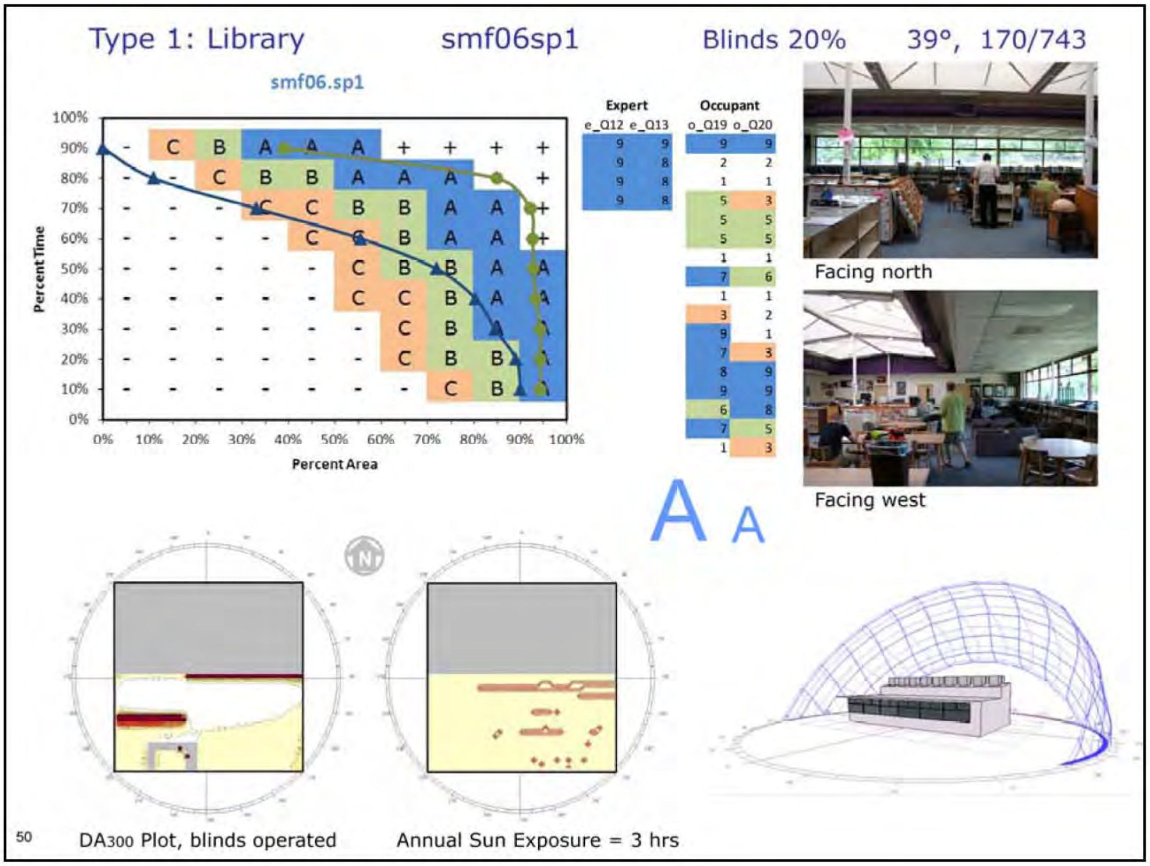
North facing office in Sacramento. Bi-polar response of occupants may reflect



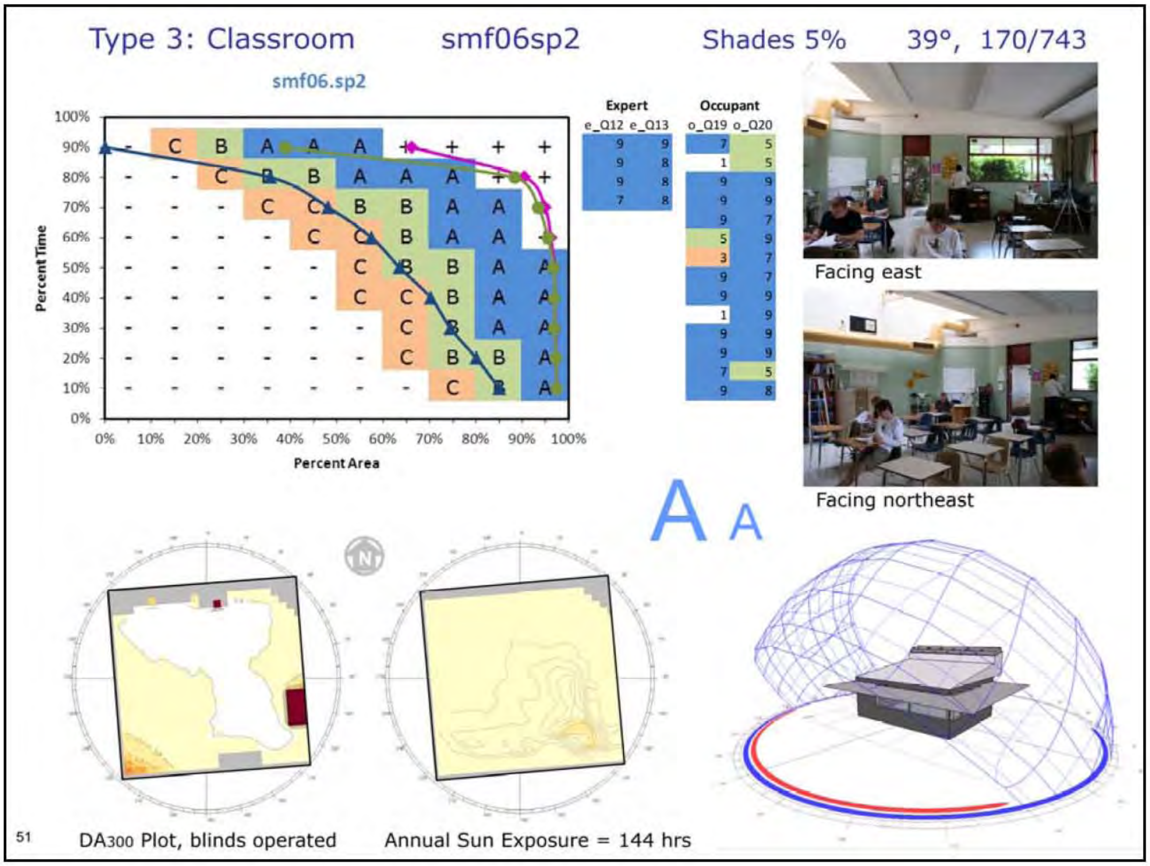
North facing office with splayed skylights. Annual plot overpredicts occupant



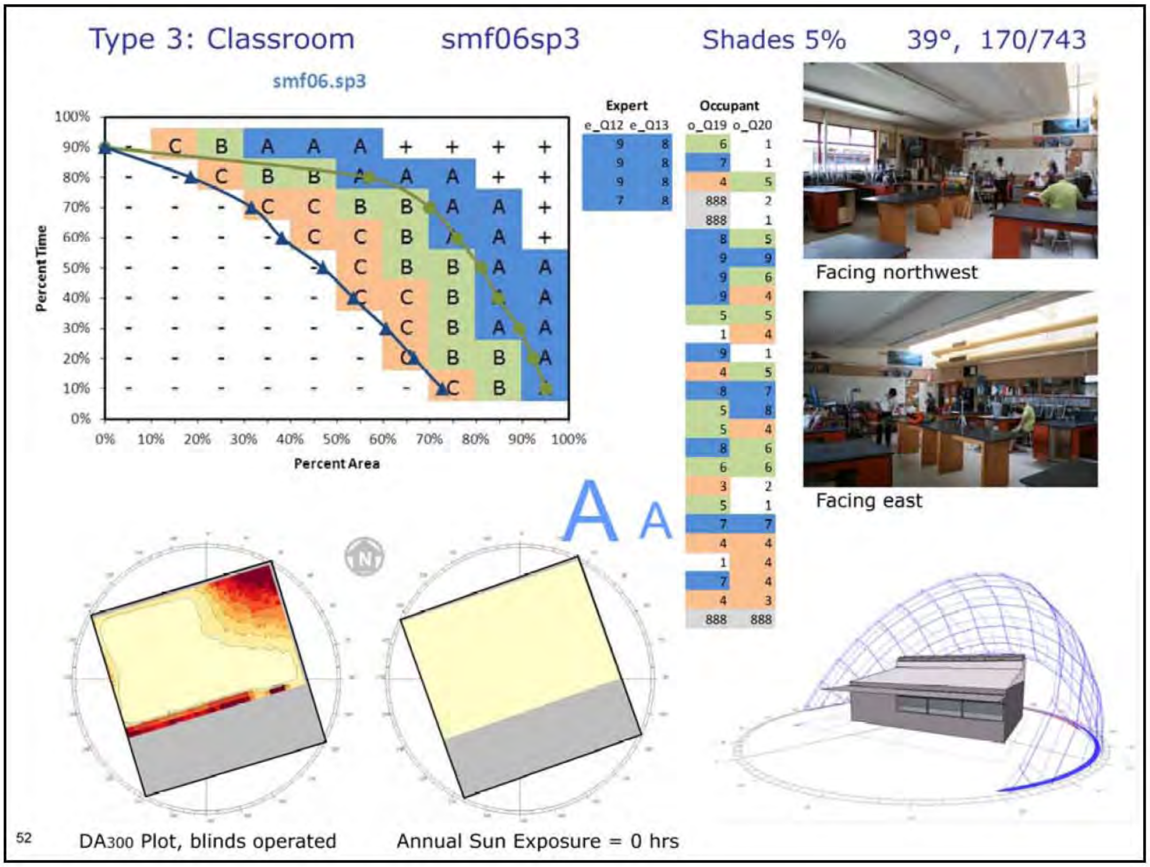
Office in Sacramento with skylights above a diffusing ceiling. Highly uniform. Acceptance by both occupants and experts predicted by annual plot. Lights on



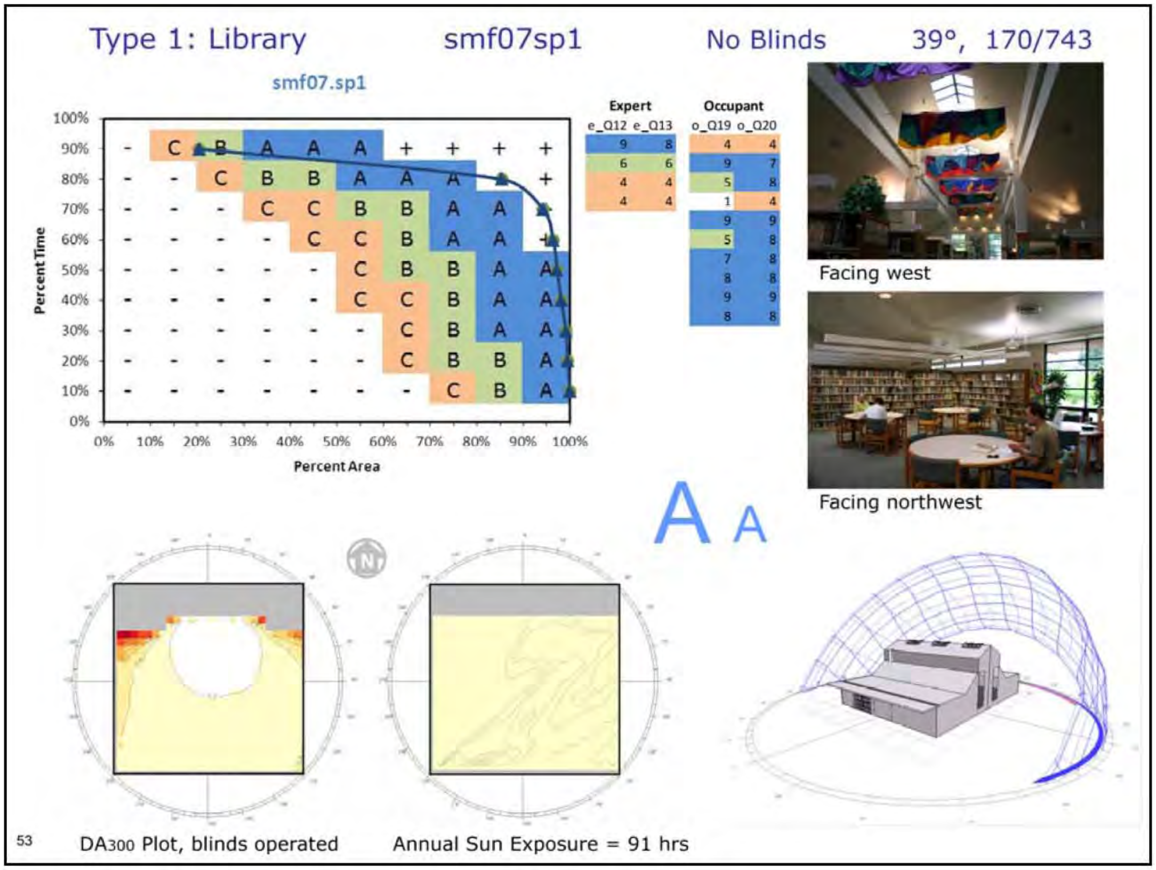
High school library in Sacramento with large north window to landscaped view and very large central skylight. Annual plot over predicts occupant assessment. Contrast between central skylit area and far corners of library



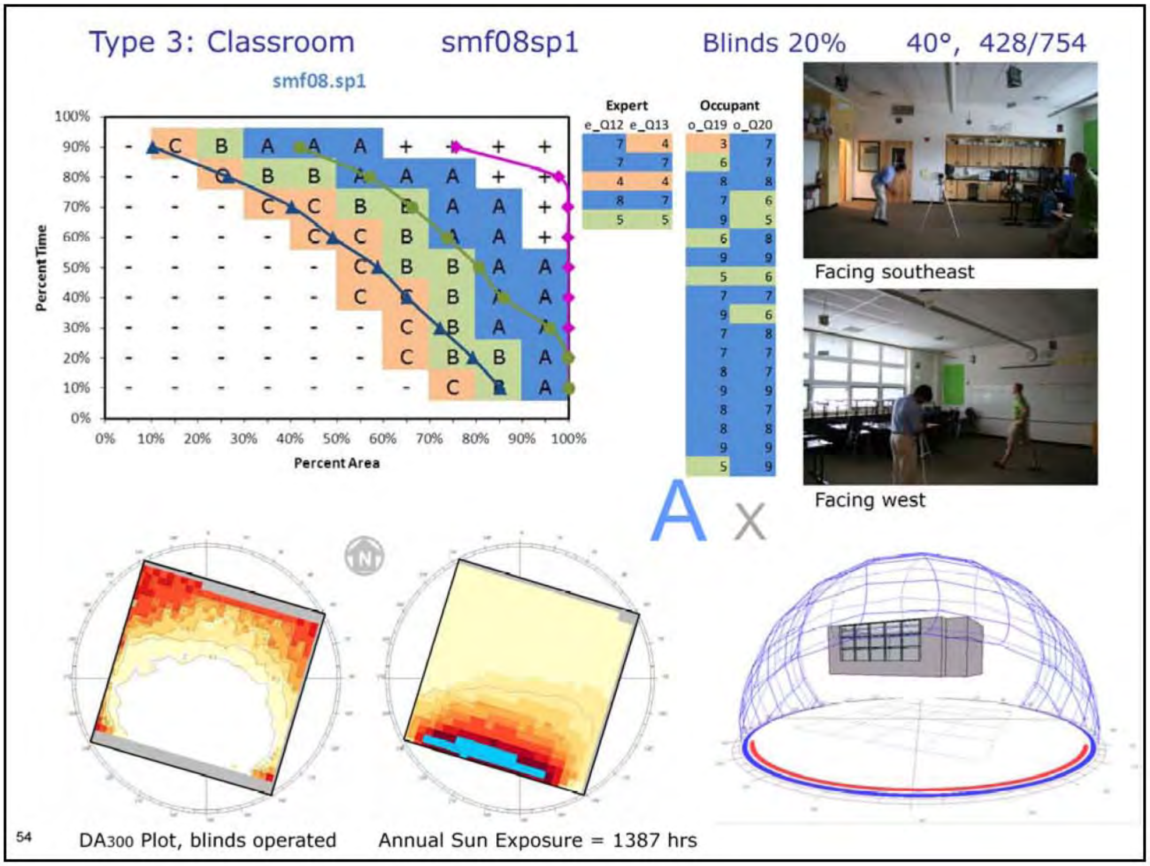
Highschool classroom in Sacramento with linear skylight along interior wall, and well shaded view windows to south and east. Highly positive assessment



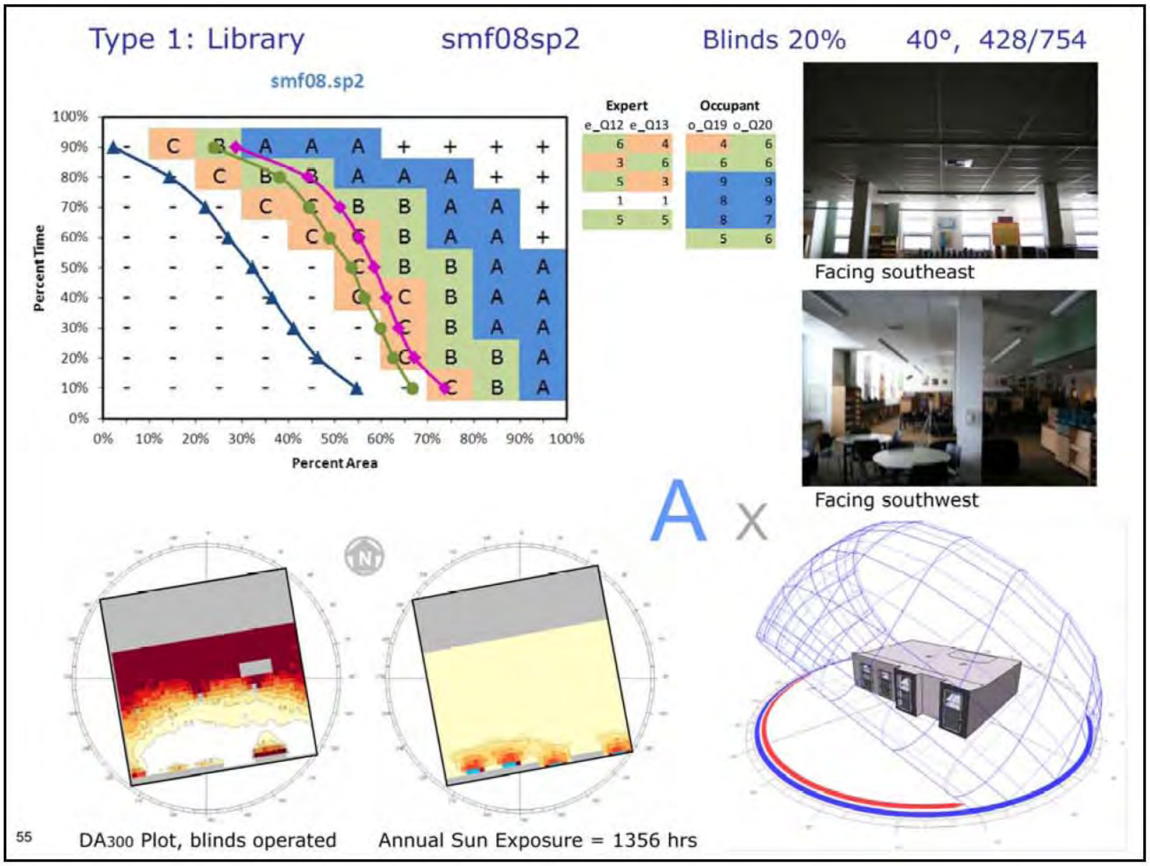
Science classroom in Sacramento with linear skylight along interior wall, and well shaded view windows to north and west. Occupants more positive about being able to work with electric lights off, then if there is always sufficient daylight. Annual plot overpredicts occupant assessment. Lights on manual



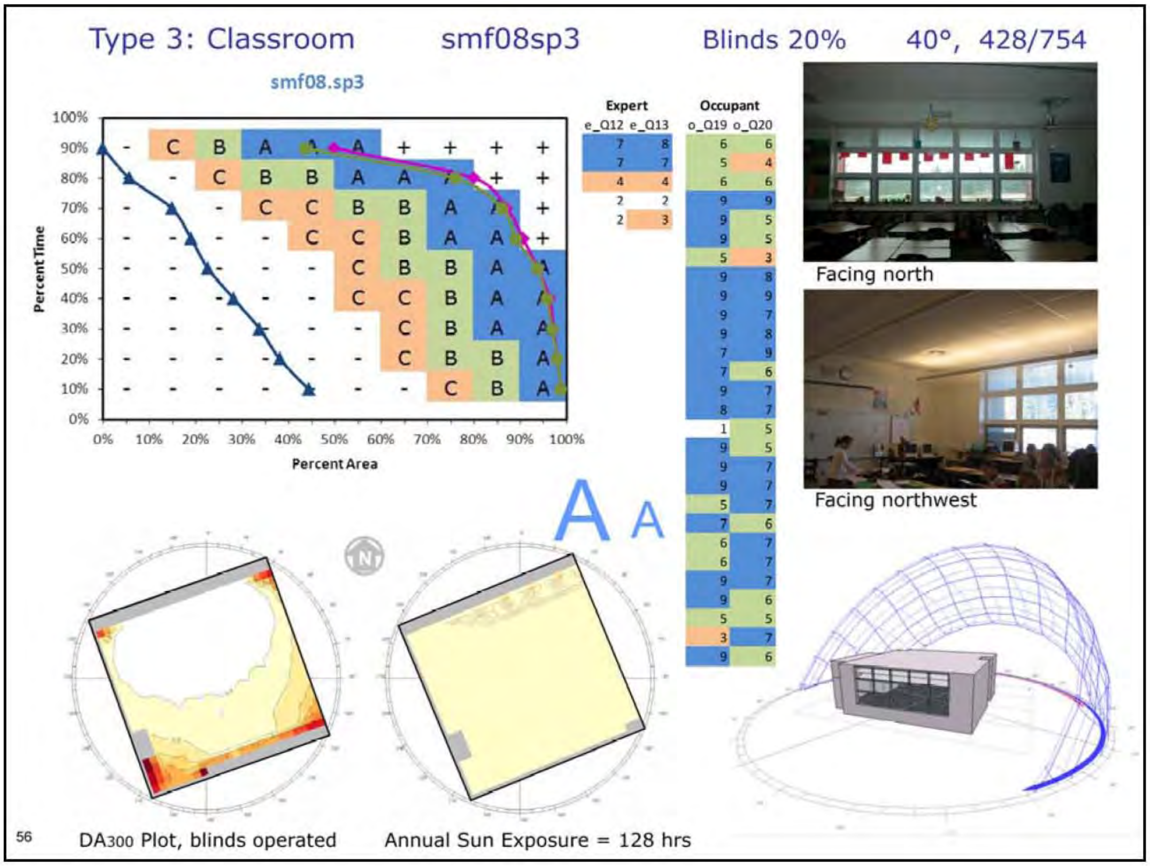
Library reading area centered around north facing window, with some contribution form skylights to the north. Experts more negative than occupants. Occupants probably experienced larger area, perhaps more under



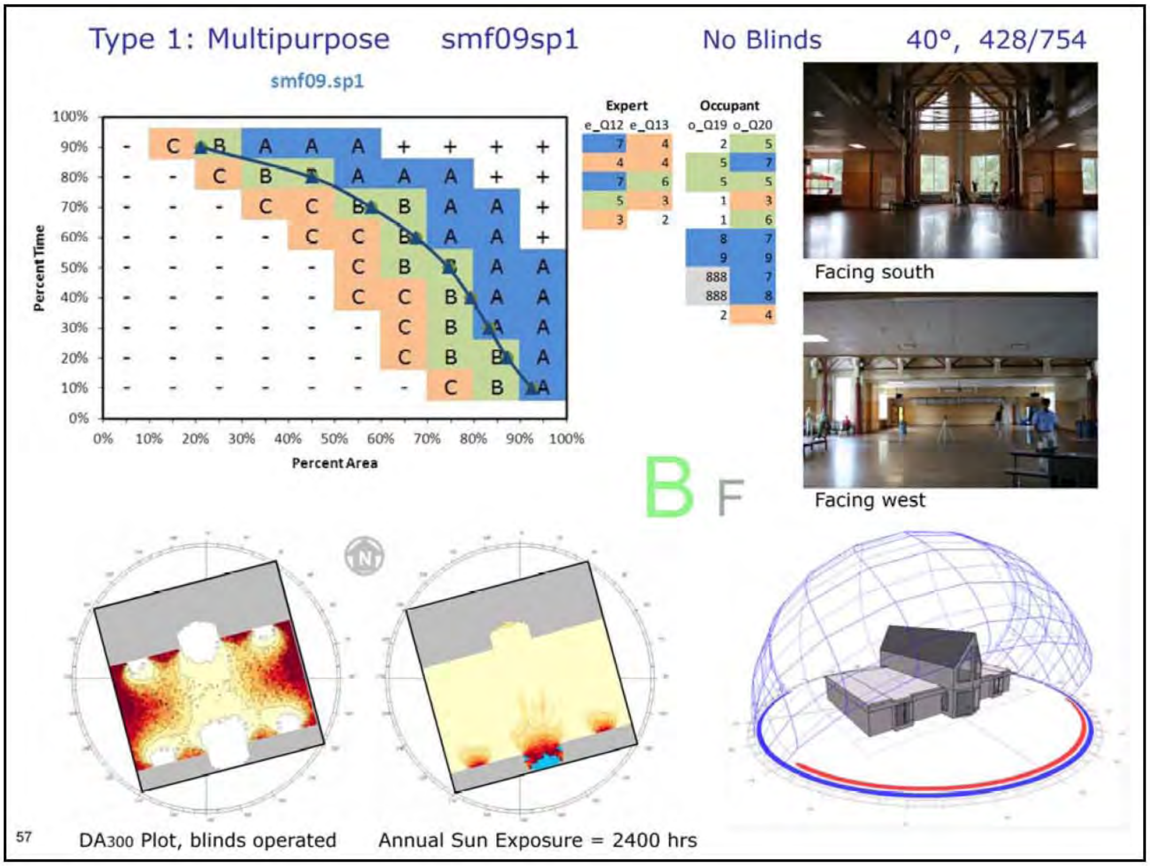
South facing classroom with inverted, embeded blinds. Strong occupant



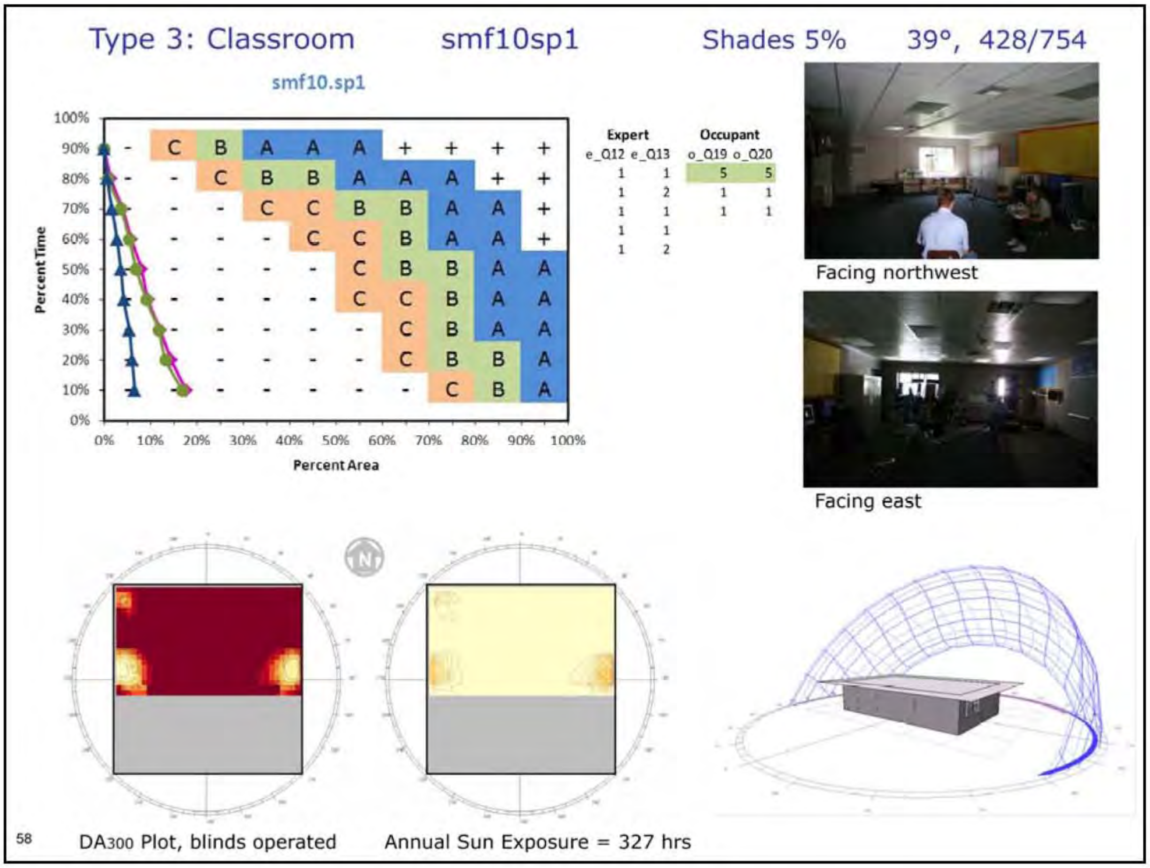
South facing library with inverted, embeded blinds. Annual plots underpredicts occupant assessment. Daylit study area probably taken too deep. Lights on



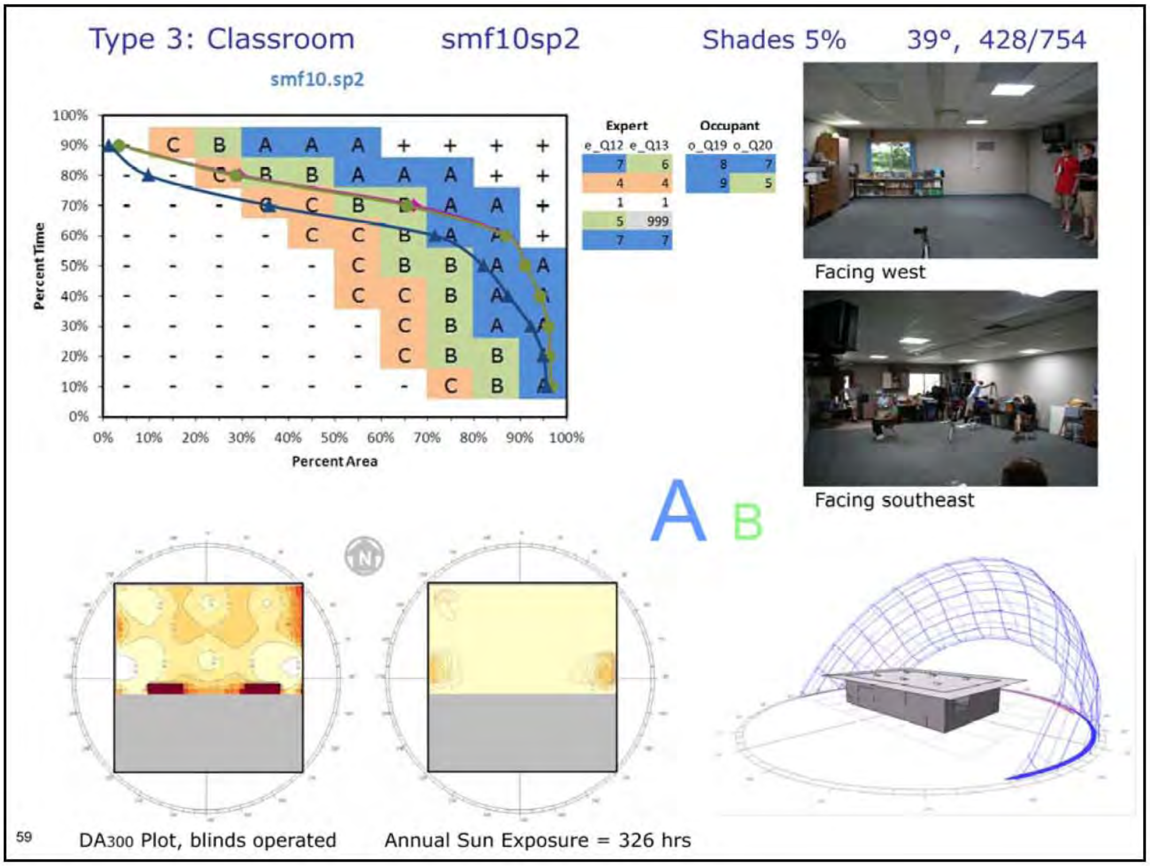
North facing classroom in CA mountains with interverted, embeded blinds. Annual simulation slightly overpredicts occupant acceptance, but both quite



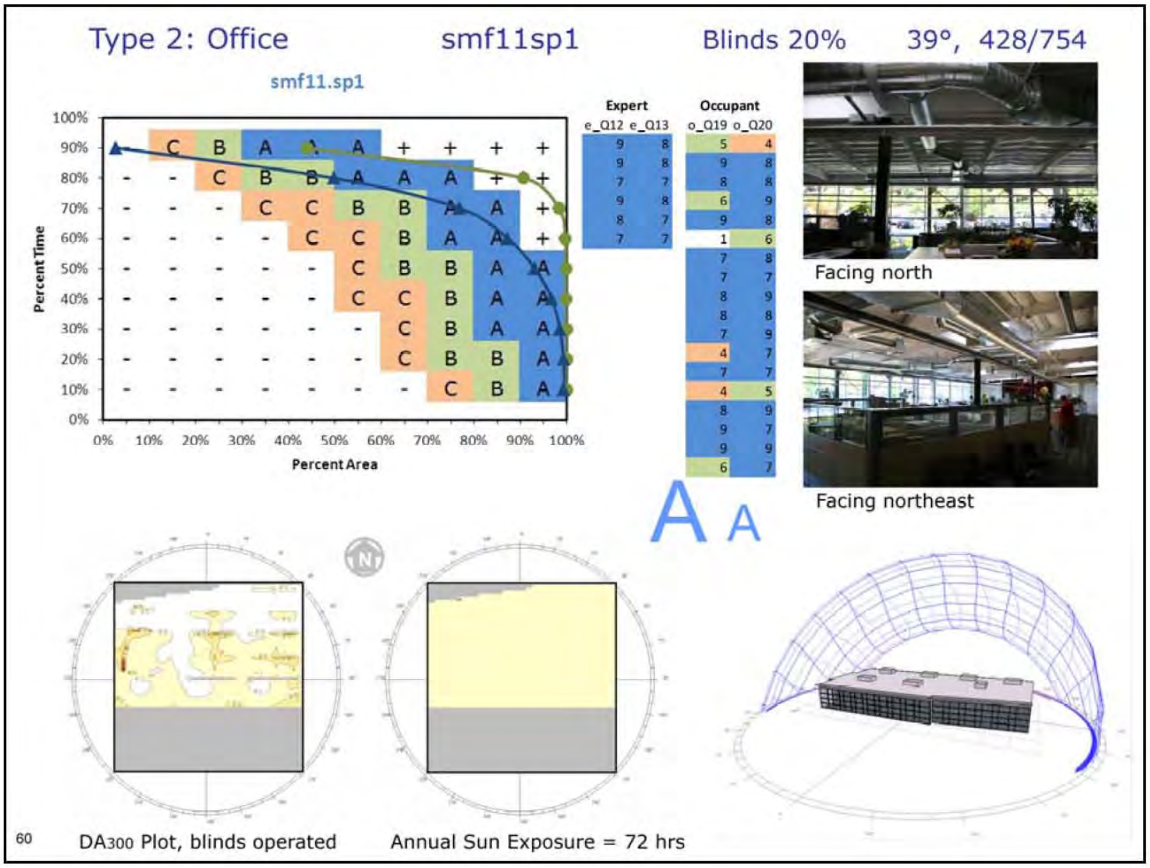
High school multipurpose room in CA mountains. Strong contrast via unshaded punched windows with views, although some balancing of daylight form two sides. Annual plot slightly underpredicts acceptance by occupants.



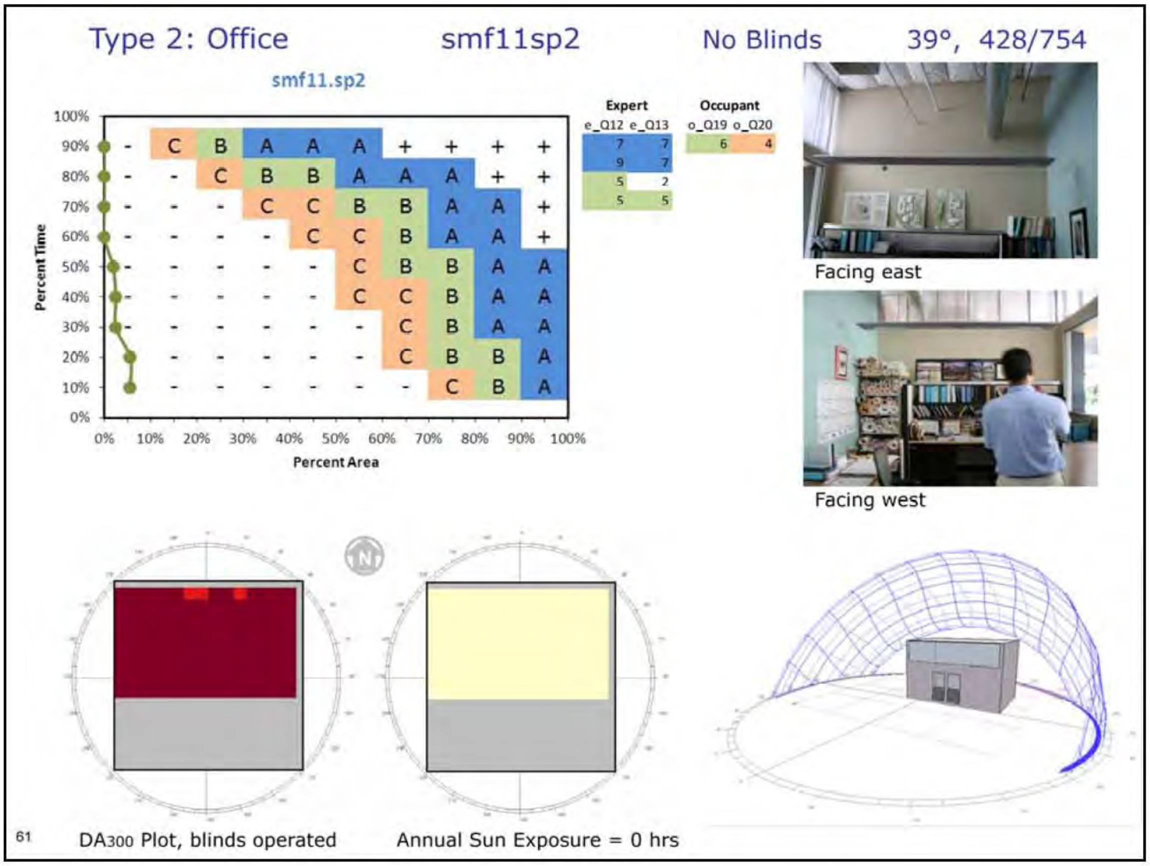
Portable classroom, had worst rating among experts, and low form occupants.



Identical portable classroom to previous, but with 6 tubular skylights added. Acceptance has increased. Mixed assessments predicted by the annual plot.



North facing windows with pleasant landscape view and lots of skylight. Very high level of acceptance predicted by annual illumination levels. Lights on



Interior small office with borrowed light from skylights. Dim but uniform. Note directionality of light in top photo. Long term occupant is OK – 6 – with turning all the lights off sometimes. Uniformity, and some sense of view to room